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Vitthaladevuni et al.

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(45) **Date of Patent: Mar. 29, 2016**

(54) **METHOD AND APPARATUS FOR AVAILABLE BANDWIDTH ESTIMATION BY A USER EQUIPMENT IN IDLE AND/OR CONNECTED MODE**

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(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 395 days.

(21) Appl. No.: **13/871,242**

(22) Filed: **Apr. 26, 2013**

(65) **Prior Publication Data**

US 2014/0029455 A1 Jan. 30, 2014

Related U.S. Application Data

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(51) **Int. Cl.**
H04W 24/02 (2009.01)
H04W 48/18 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 24/02*** (2013.01); ***H04W 48/18*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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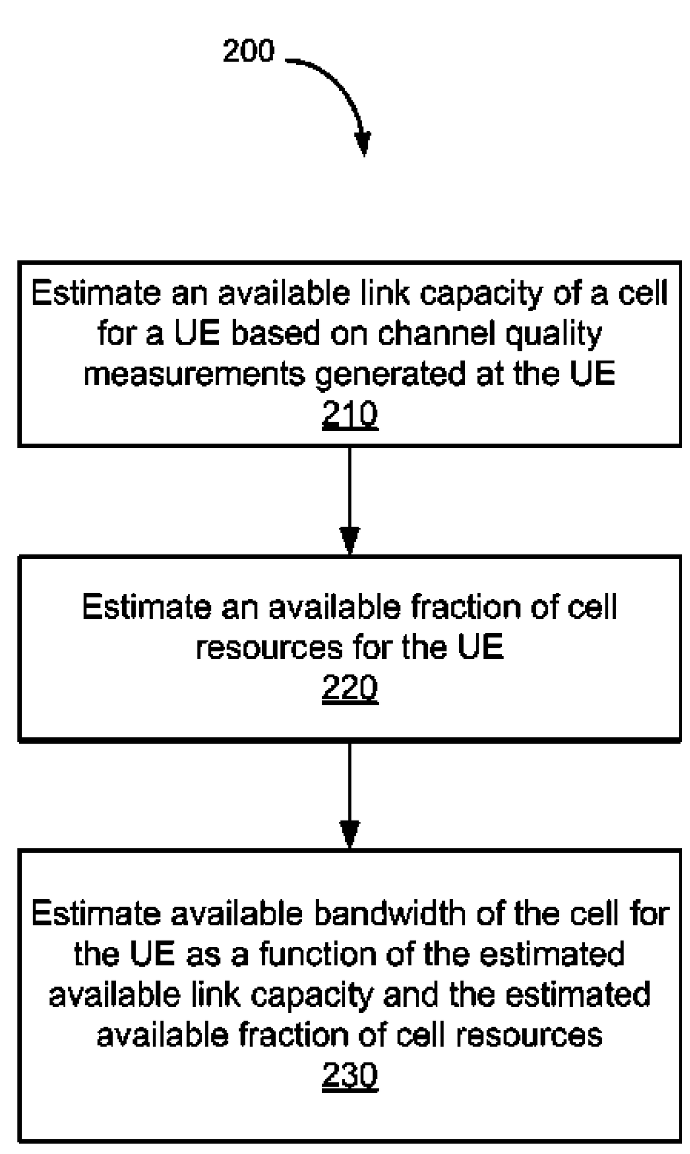
(Continued)

Primary Examiner — Feben M Haile
(74) *Attorney, Agent, or Firm* — François A. Pelaez

(57) **ABSTRACT**

A method and apparatus for determining available downlink bandwidth are described. The described aspects may include estimating an available link capacity of a cell for a user equipment. The described aspects may include estimating an available fraction of cell resources for the user equipment. The described aspects may include estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources. Available bandwidth may be estimated for a cell in a Universal Mobile Telecommunications System (UMTS) system when the user equipment is in an idle mode and/or a connected mode. Available bandwidth may be estimated for a cell in a Long Term Evolution (LTE) system when the user equipment is in an idle mode and/or a connected mode.

59 Claims, 25 Drawing Sheets



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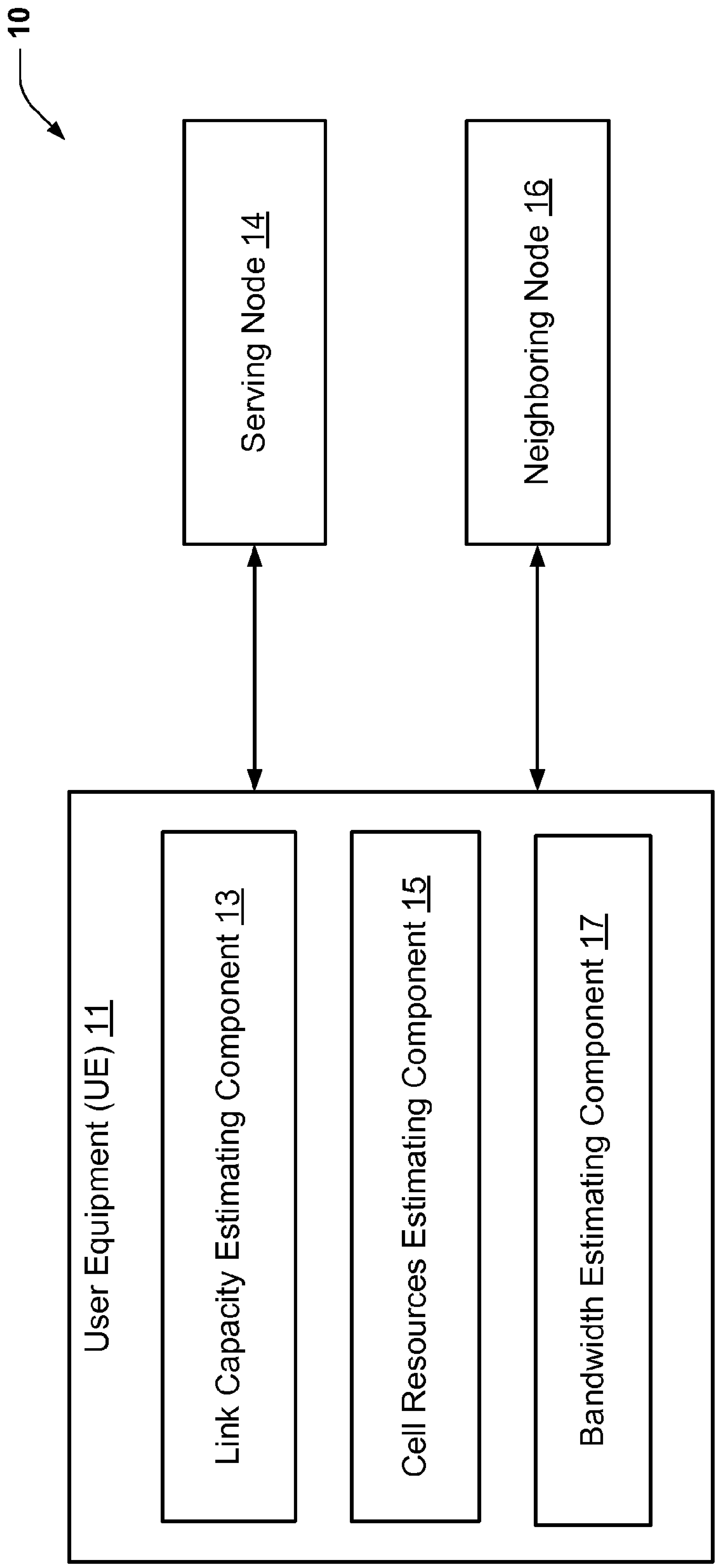

10
Serving Node 14
Neighboring Node 16
User Equipment (UE) 11
Link Capacity Estimating Component 13
Cell Resources Estimating Component 15
Bandwidth Estimating Component 17

FIG. 1

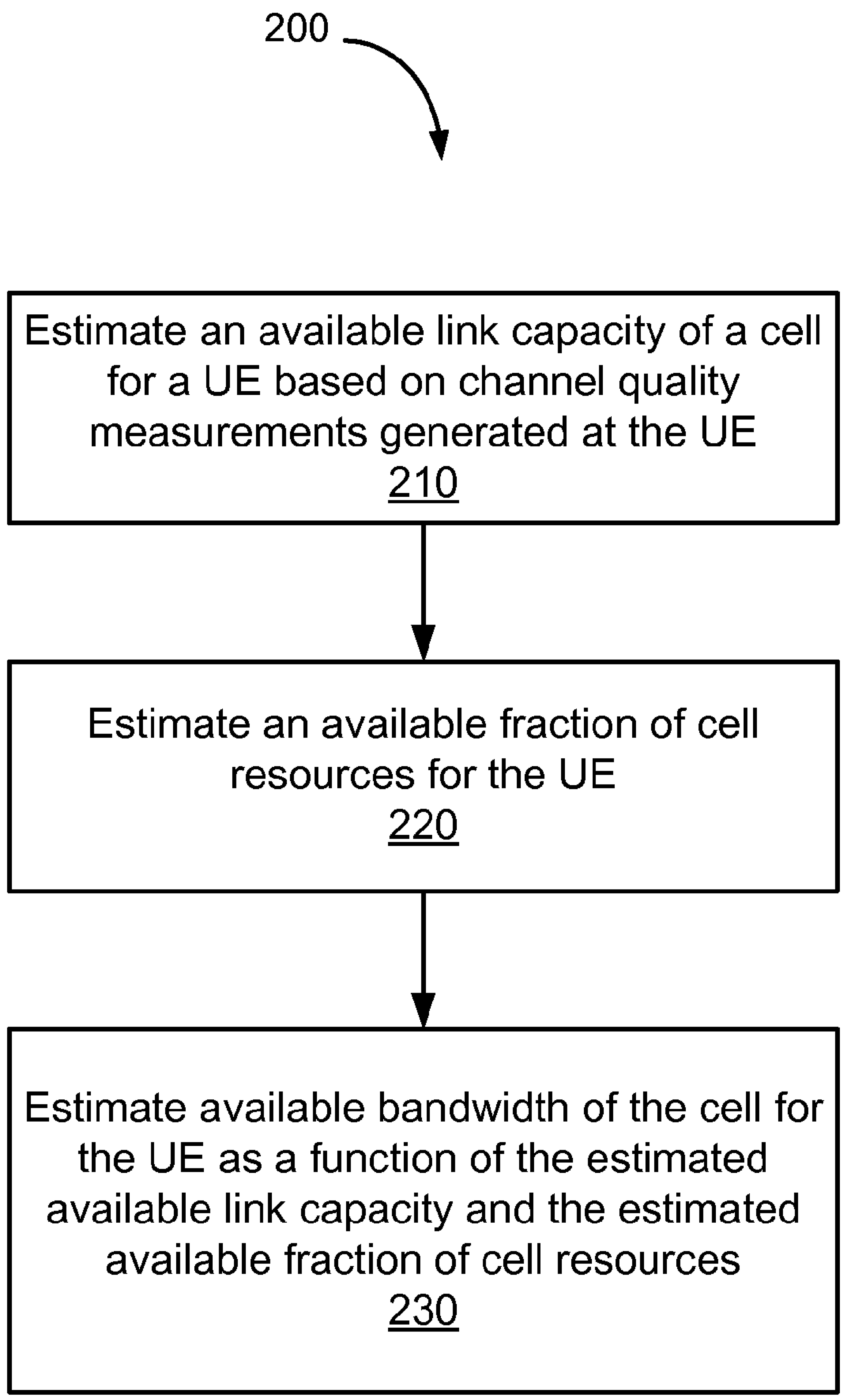

200
Estimate an available link capacity of a cell for a UE based on channel quality measurements generated at the UE
210
Estimate an available fraction of cell resources for the UE
220
Estimate available bandwidth of the cell for the UE as a function of the estimated available link capacity and the estimated available fraction of cell resources
230

FIG. 2

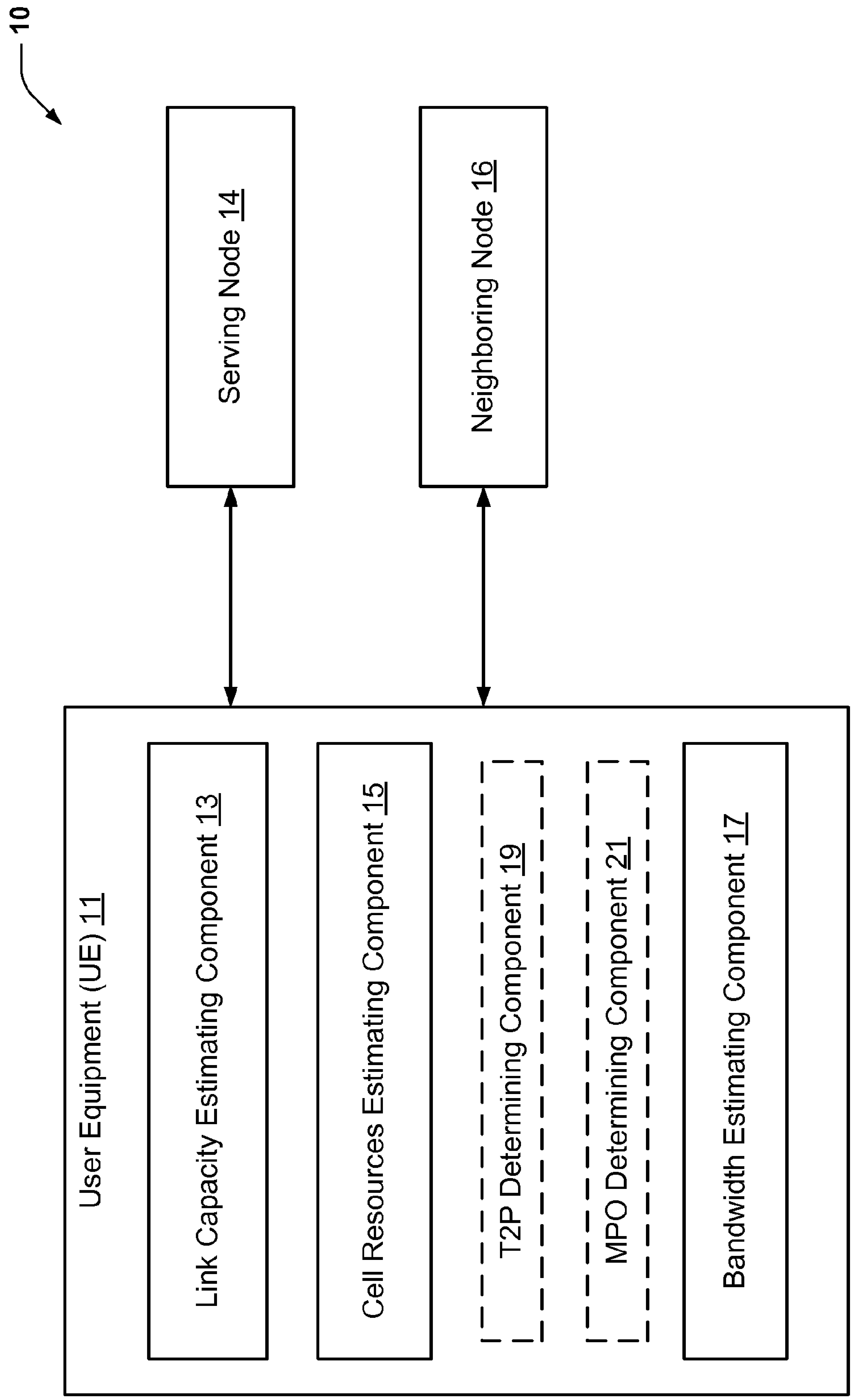

10
Serving Node 14
Neighboring Node 16
User Equipment (UE) 11
Link Capacity Estimating Component 13
Cell Resources Estimating Component 15
T2P Determining Component 19
MPO Determining Component 21
Bandwidth Estimating Component 17

FIG. 3

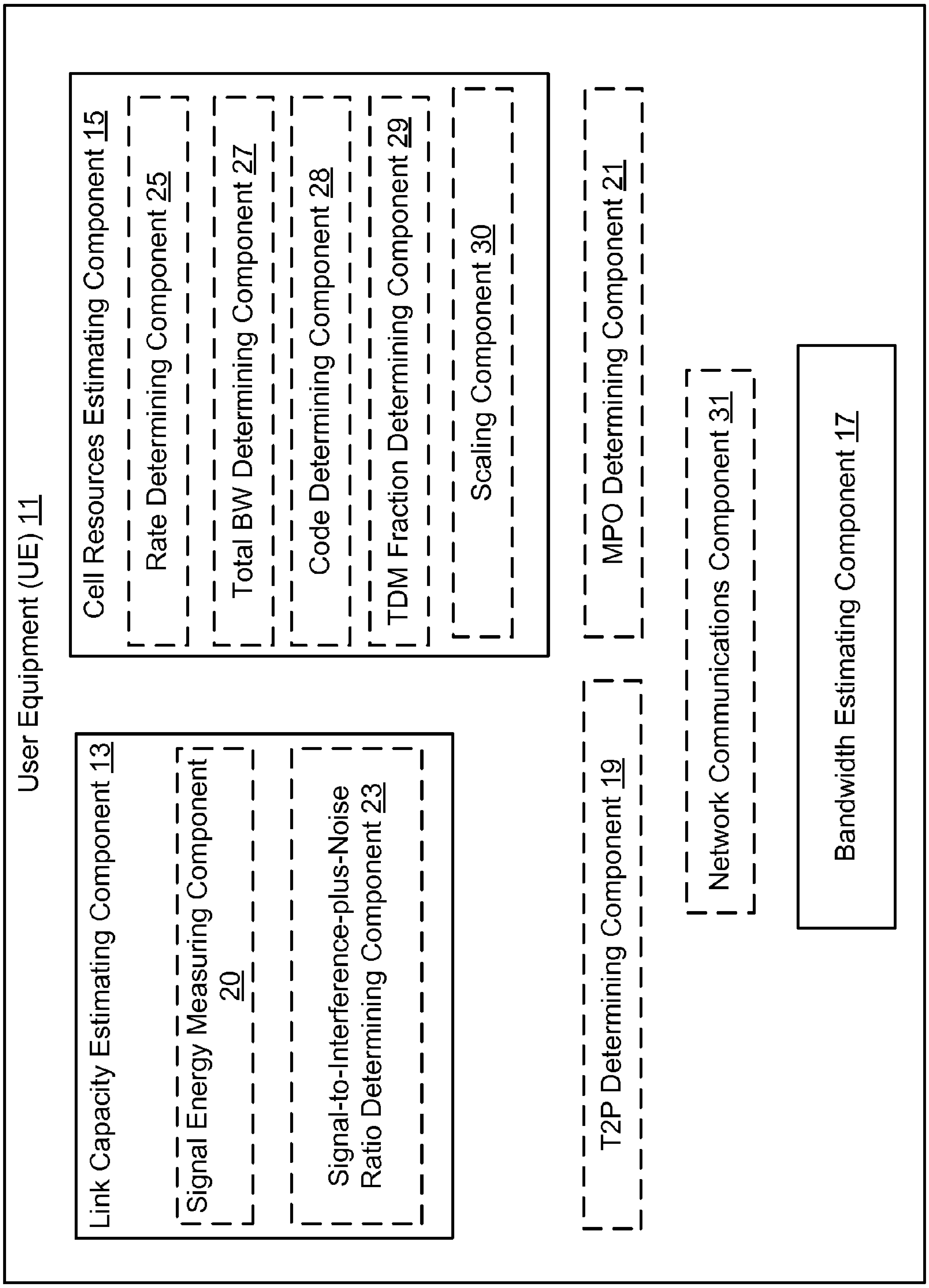

User Equipment (UE) 11
Link Capacity Estimating Component 13
Signal Energy Measuring Component 20
Signal-to-Interference-plus-Noise Ratio Determining Component 23
Cell Resources Estimating Component 15
Rate Determining Component 25
Total BW Determining Component 27
Code Determining Component 28
TDM Fraction Determining Component 29
Scaling Component 30
T2P Determining Component 19
MPO Determining Component 21
Network Communications Component 31
Bandwidth Estimating Component 17

FIG. 4

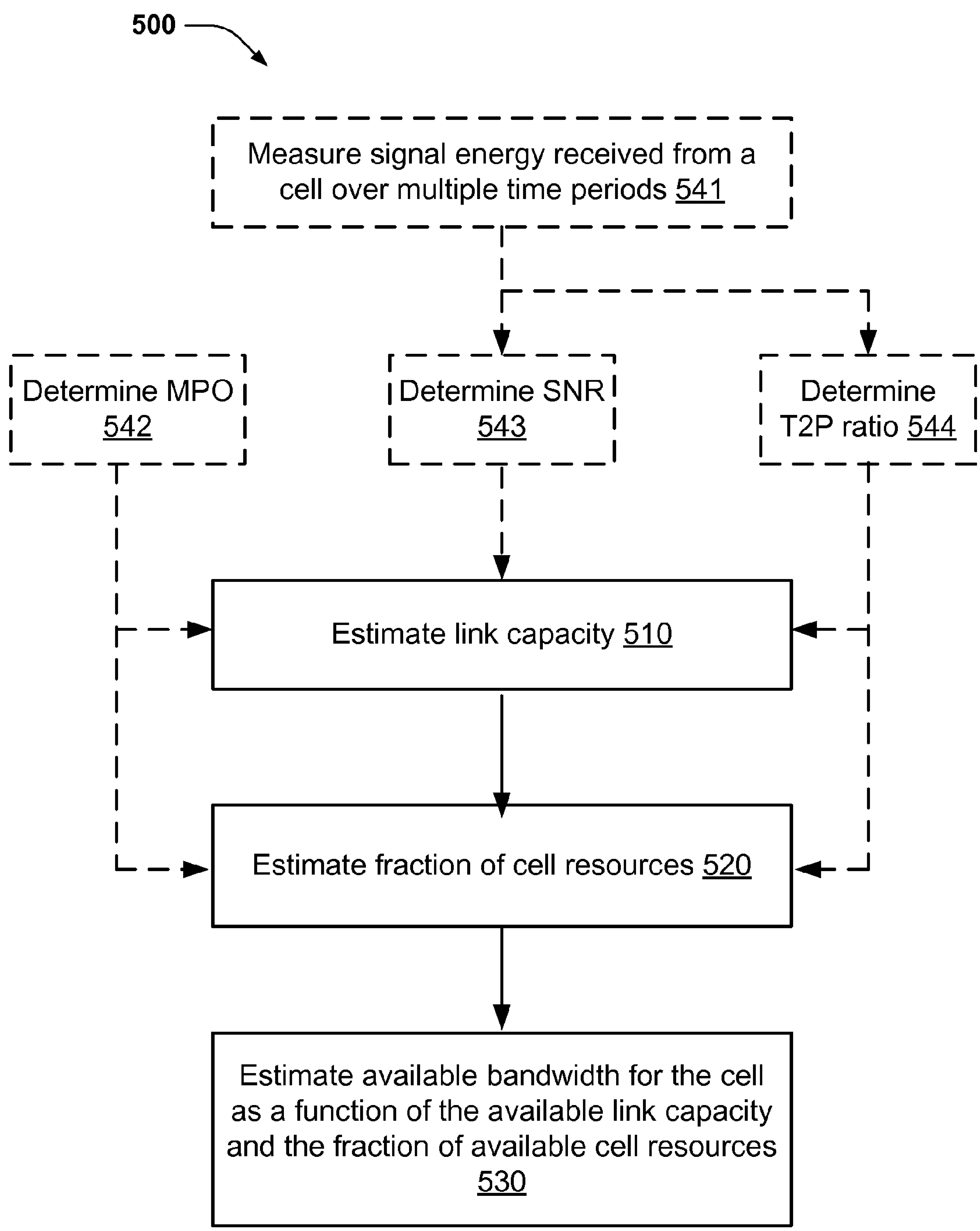

500
Measure signal energy received from a cell over multiple time periods 541
Determine MPO 542
Determine SNR 543
Determine T2P ratio 544
Estimate link capacity 510
Estimate fraction of cell resources 520
Estimate available bandwidth for the cell as a function of the available link capacity and the fraction of available cell resources 530

FIG. 5

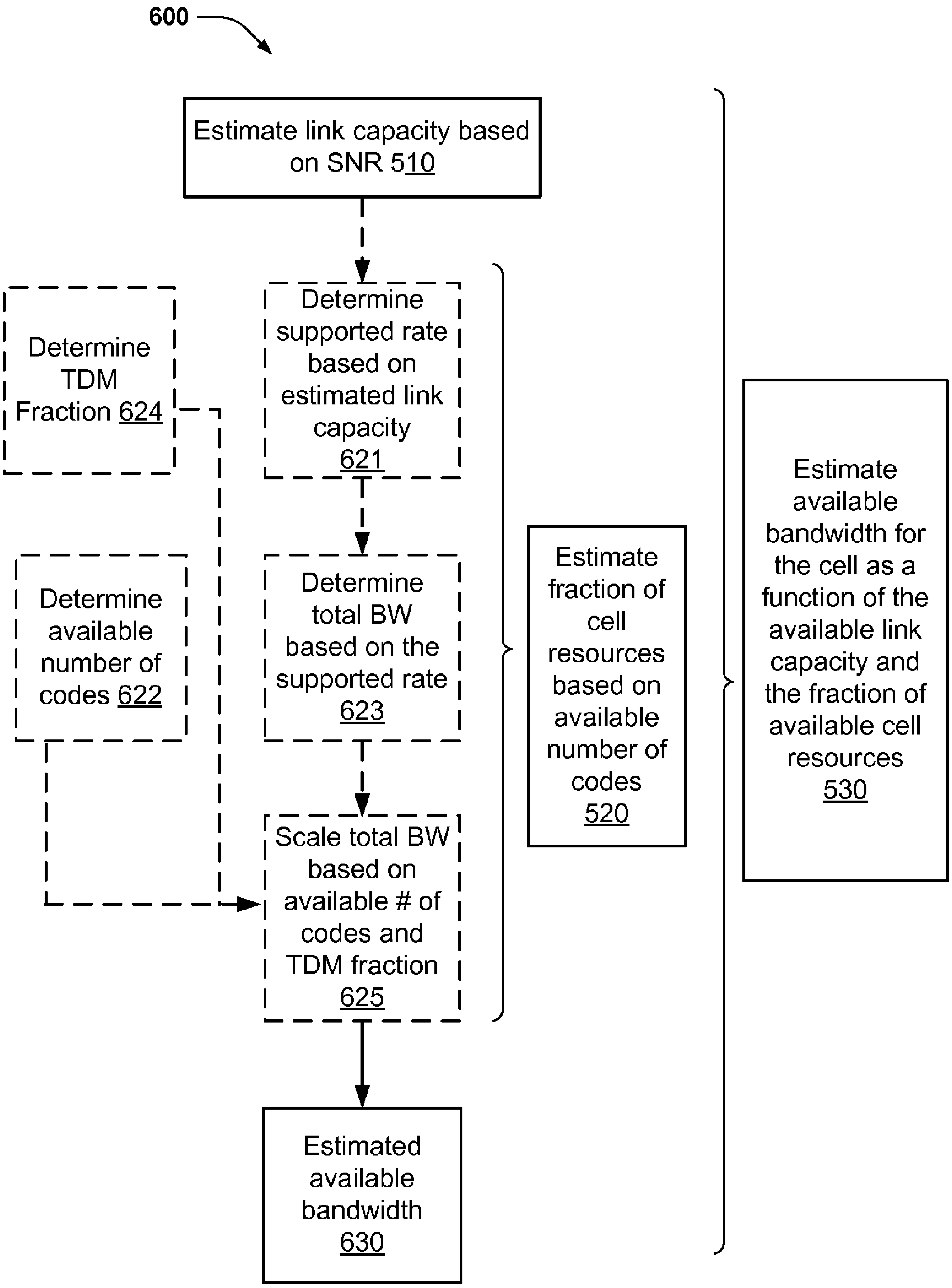

600
Estimate link capacity based on SNR 510
Determine TDM Fraction 624
Determine supported rate based on estimated link capacity 621
Determine available number of codes 622
Determine total BW based on the supported rate 623
Scale total BW based on available # of codes and TDM fraction 625
Estimated available bandwidth 630
Estimate fraction of cell resources based on available number of codes 520
Estimate available bandwidth for the cell as a function of the available link capacity and the fraction of available cell resources 530

FIG. 6

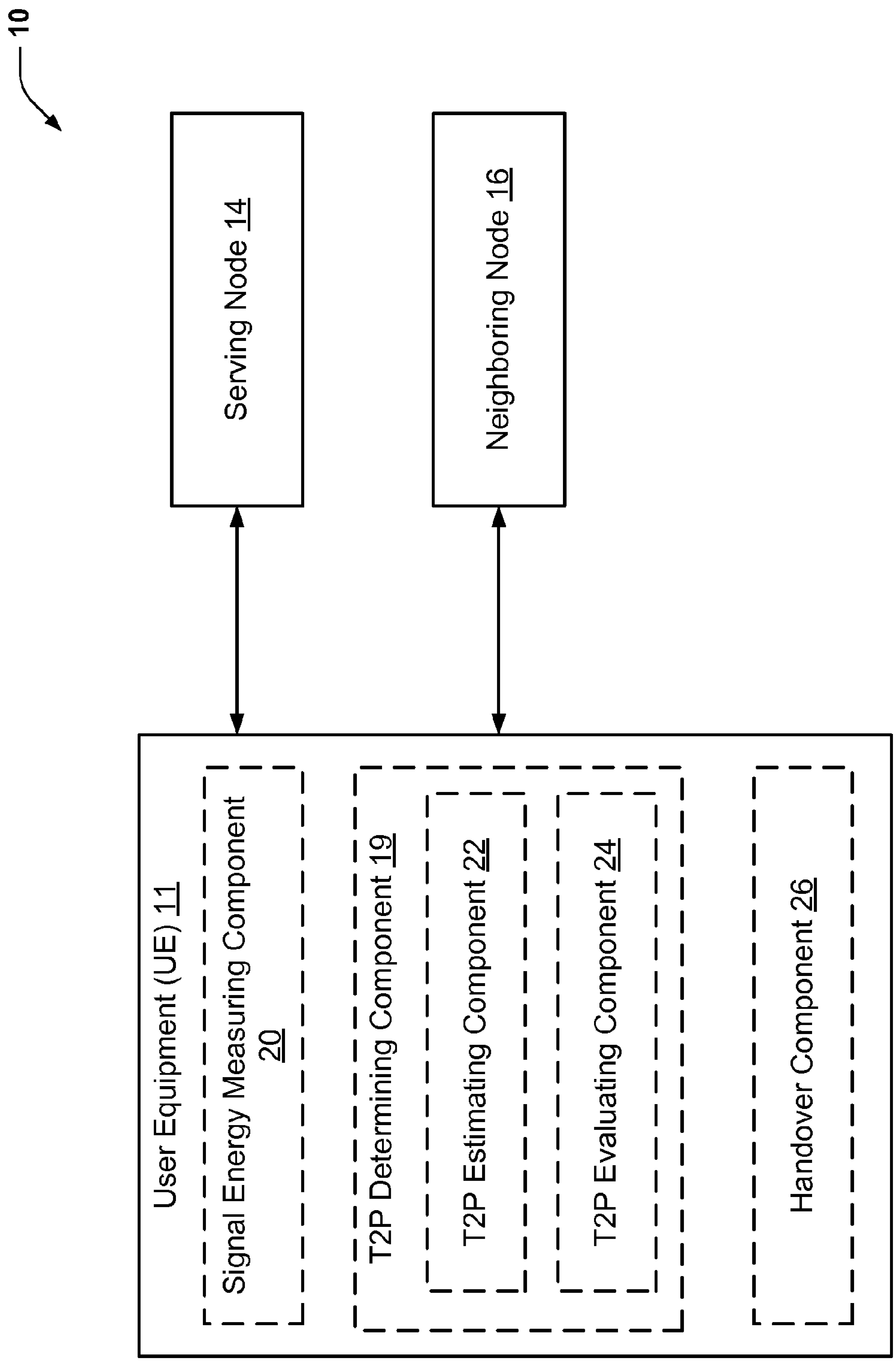

10
Serving Node 14
Neighboring Node 16
User Equipment (UE) 11
Signal Energy Measuring Component 20
T2P Determining Component 19
T2P Estimating Component 22
T2P Evaluating Component 24
Handover Component 26

FIG. 7

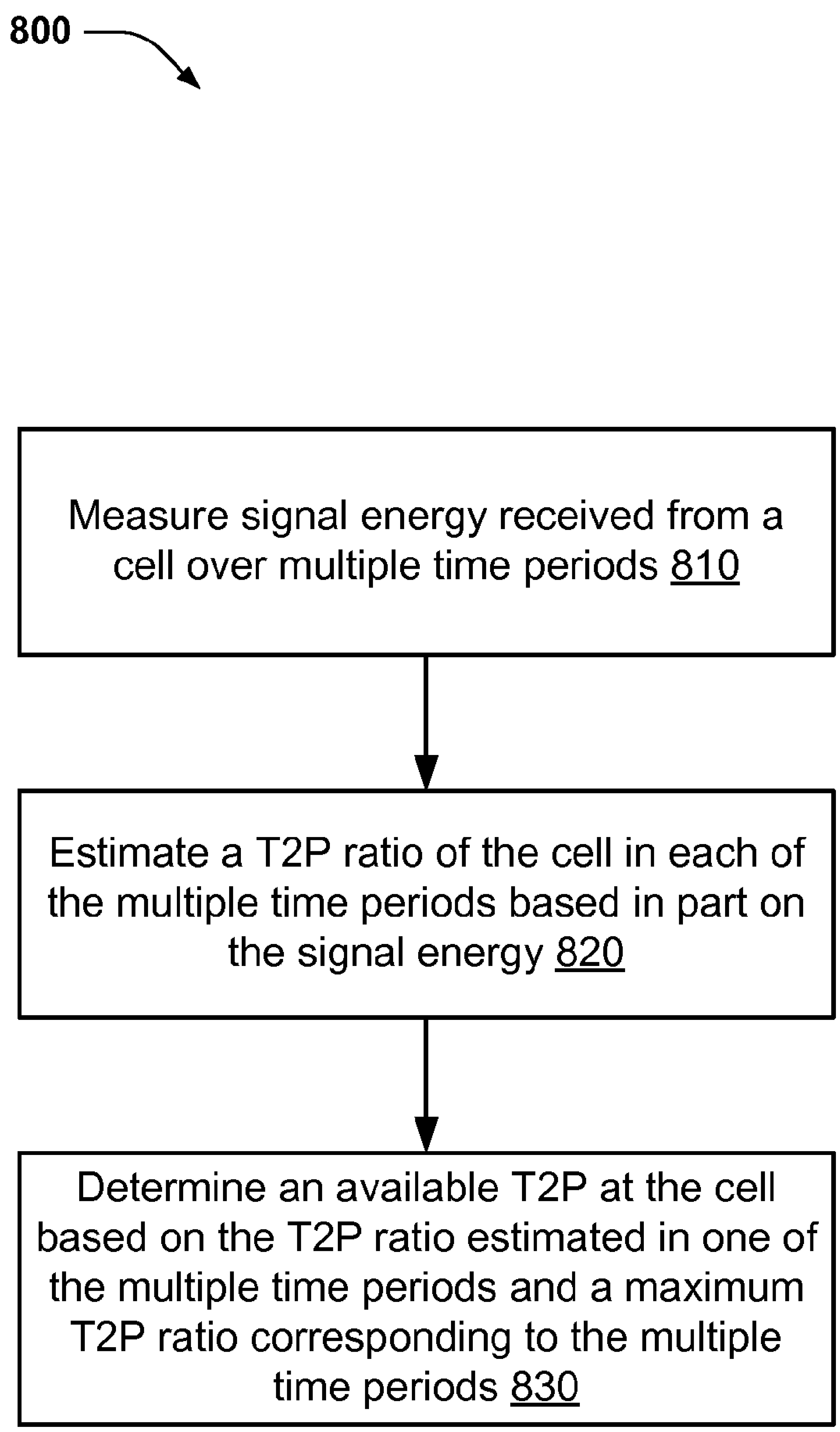

800
Measure signal energy received from a cell over multiple time periods 810
Estimate a T2P ratio of the cell in each of the multiple time periods based in part on the signal energy 820
Determine an available T2P at the cell based on the T2P ratio estimated in one of the multiple time periods and a maximum T2P ratio corresponding to the multiple time periods 830

FIG. 8

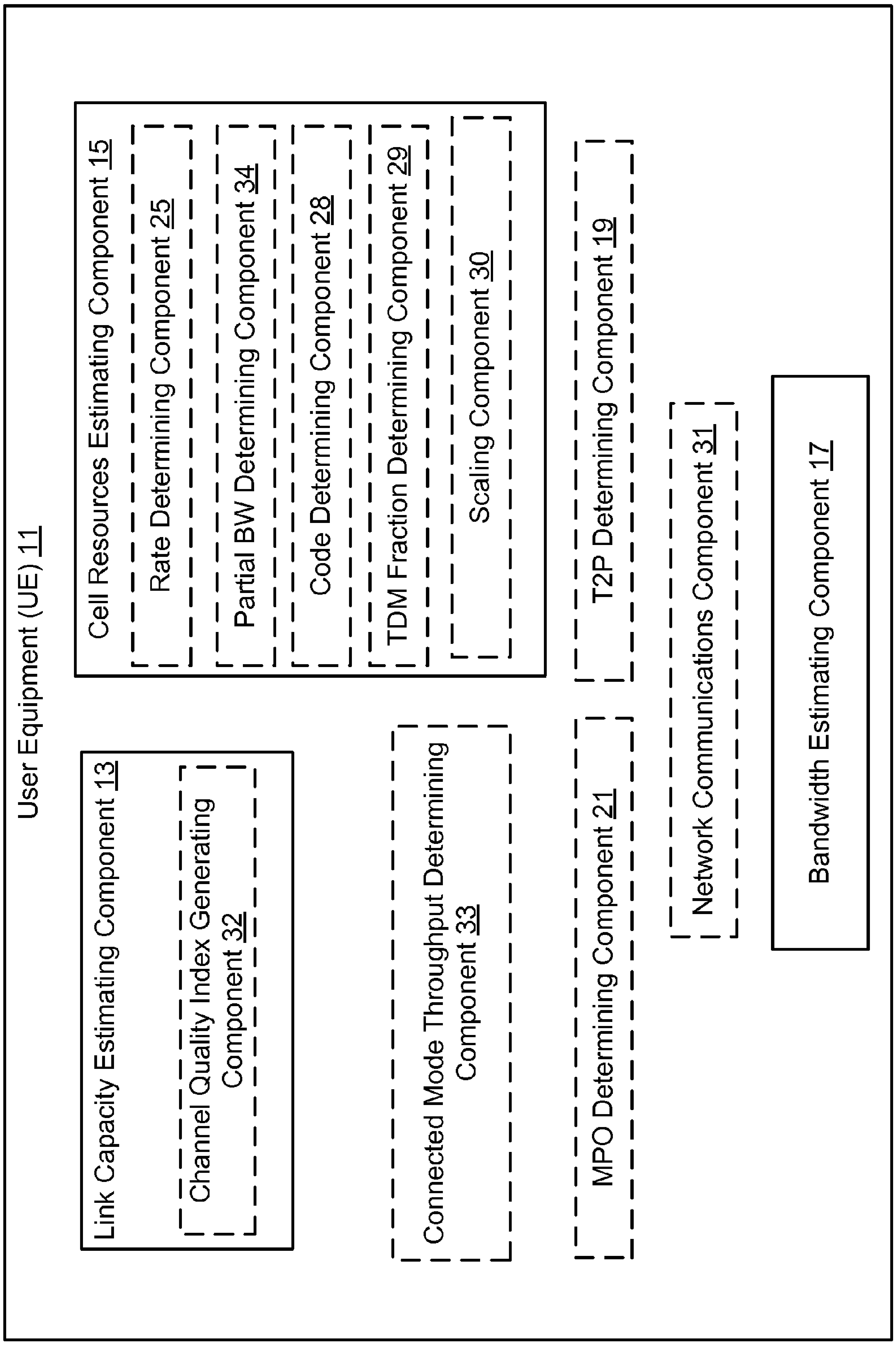

User Equipment (UE) 11
Link Capacity Estimating Component 13
Channel Quality Index Generating Component 32
Connected Mode Throughput Determining Component 33
MPO Determining Component 21
Cell Resources Estimating Component 15
Rate Determining Component 25
Partial BW Determining Component 34
Code Determining Component 28
TDM Fraction Determining Component 29
Scaling Component 30
T2P Determining Component 19
Network Communications Component 31
Bandwidth Estimating Component 17

FIG. 9

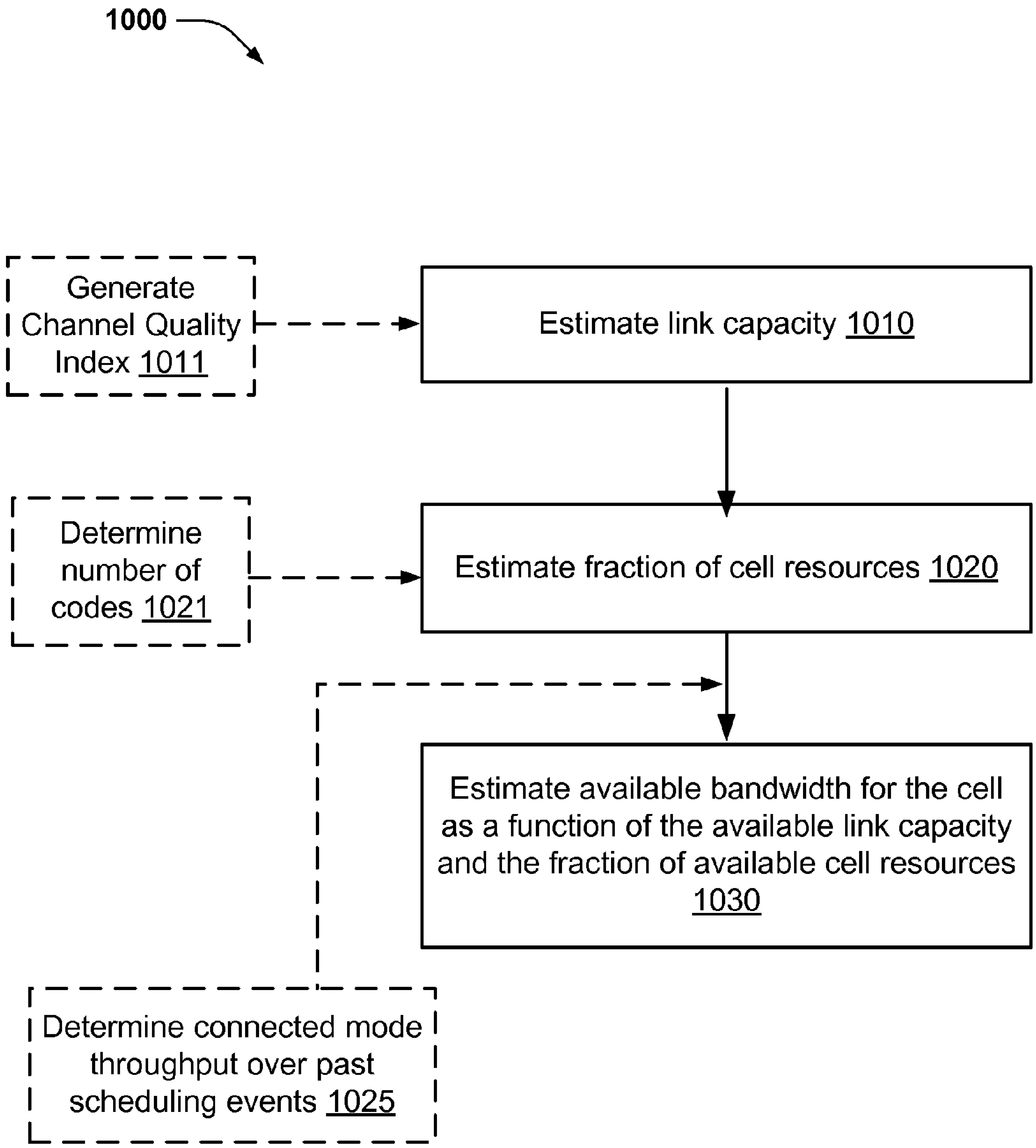

1000
Generate Channel Quality Index 1011
Estimate link capacity 1010
Determine number of codes 1021
Estimate fraction of cell resources 1020
Estimate available bandwidth for the cell as a function of the available link capacity and the fraction of available cell resources 1030
Determine connected mode throughput over past scheduling events 1025

FIG. 10

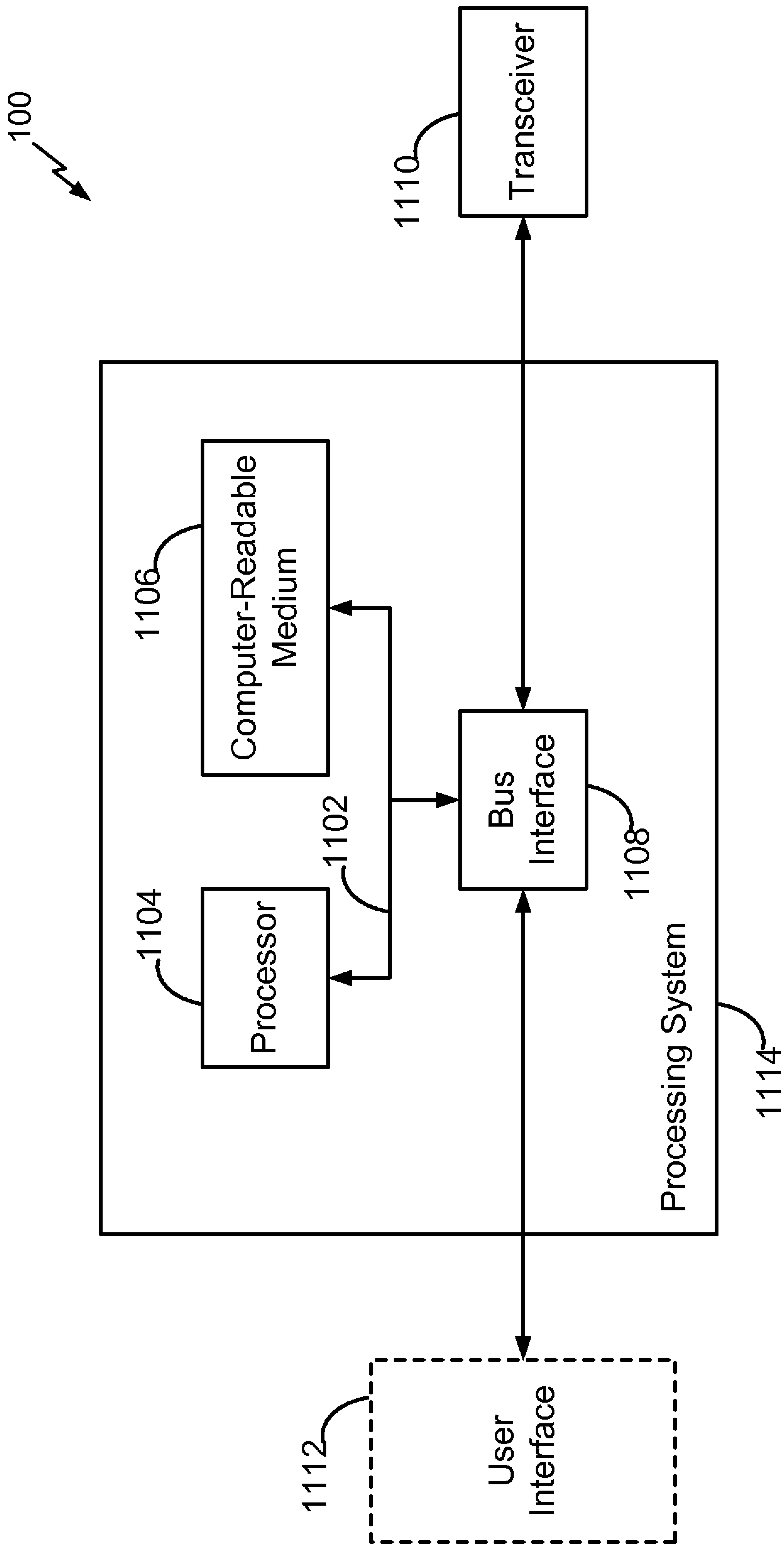

100
Transceiver
1110
Computer-Readable Medium
1106
Bus Interface
1108
1102
Processor
1104
Processing System
1114
User Interface
1112

FIG. 11

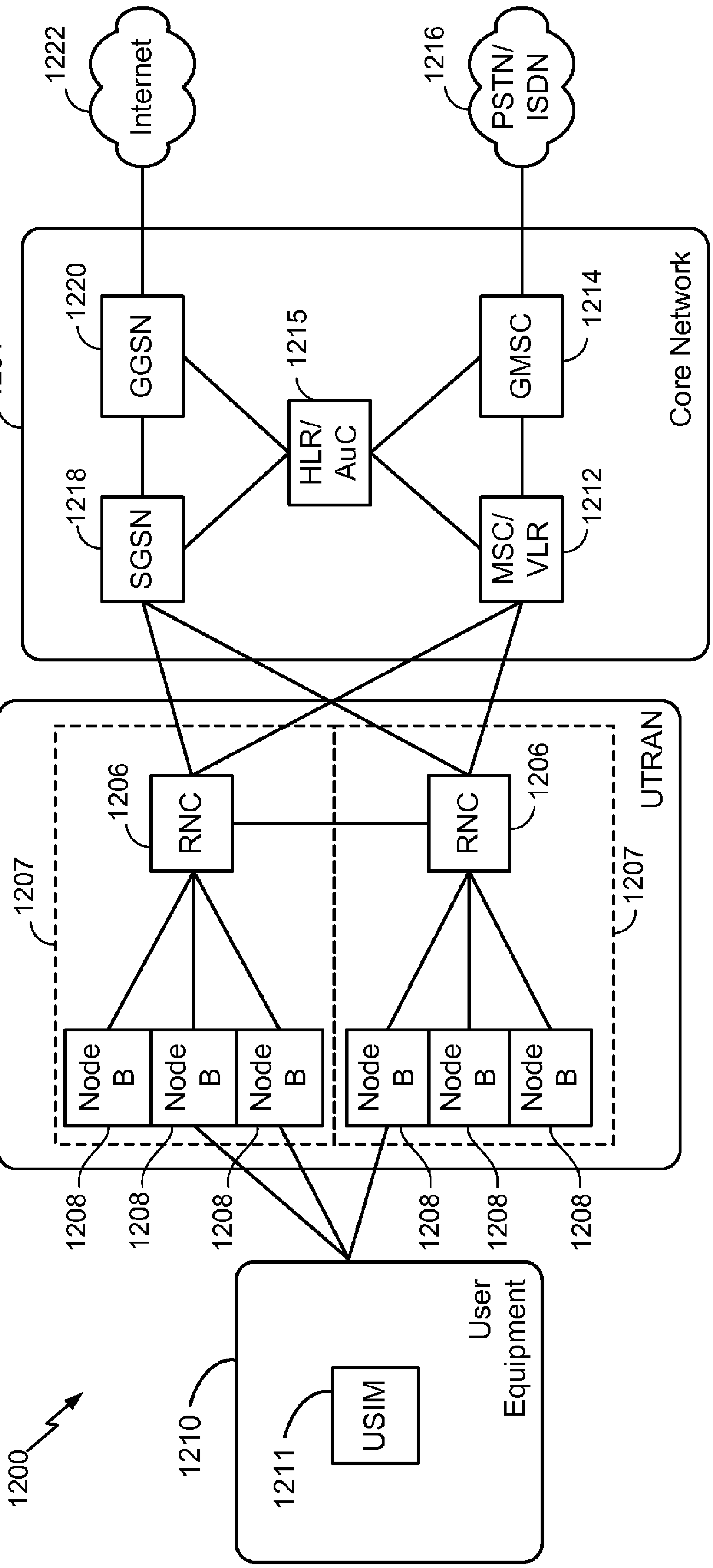

1200
1210
1211
USIM
User Equipment
1208
1208
1208
1208
1208
1208
Node B
Node B
Node B
Node B
Node B
Node B
1202
1207
1207
1206
RNC
1206
RNC
UTRAN
1204
SGSN
1218
GGSN
1220
HLR/ AuC
1215
MSC/ VLR
1212
GMSC
1214
Core Network
Internet
1222
PSTN/ ISDN
1216

FIG. 12

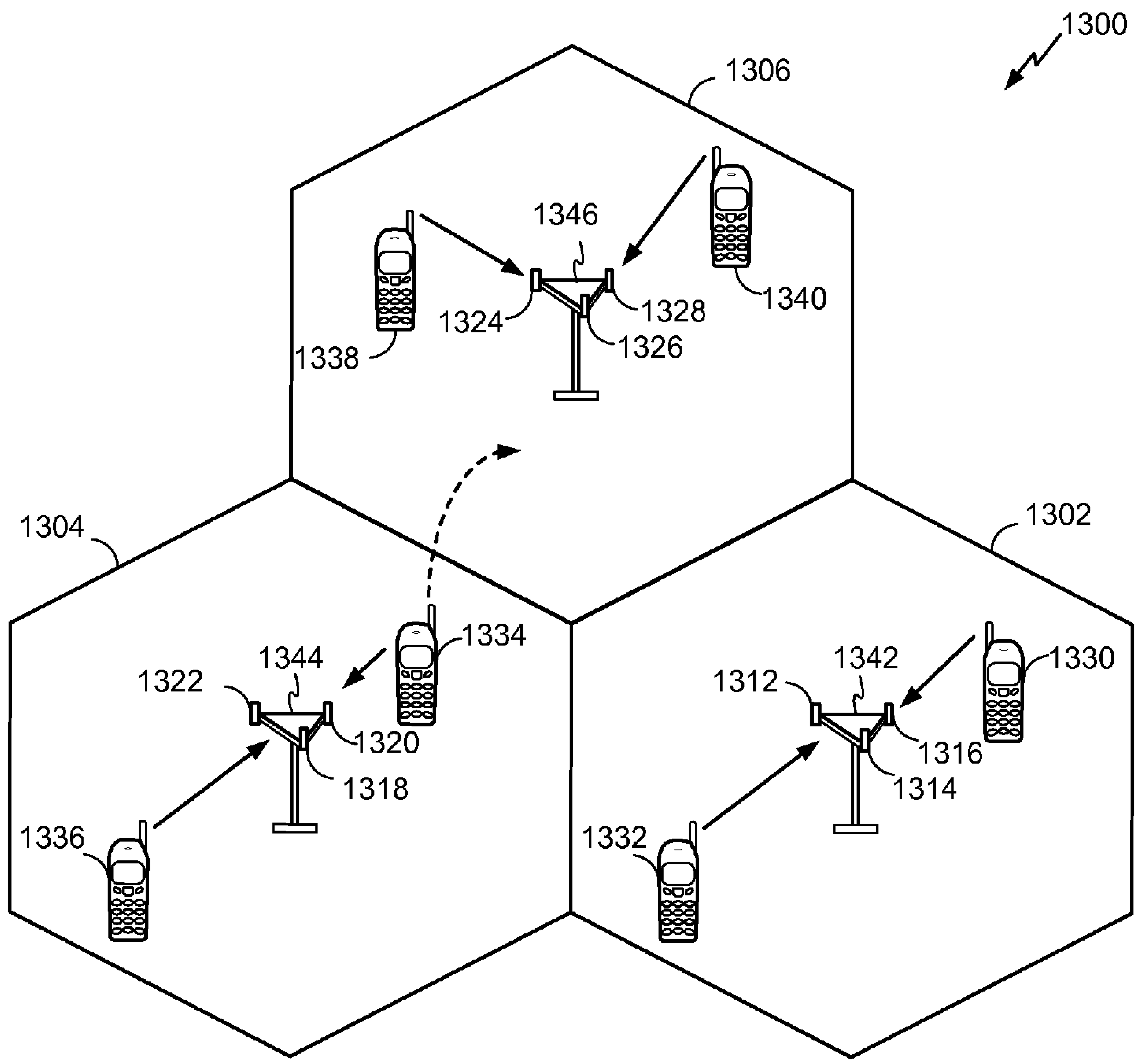

1300
1306
1346
1324
1328
1326
1338
1340
1304
1302
1334
1344
1322
1320
1318
1336
1342
1312
1330
1316
1314
1332

FIG. 13

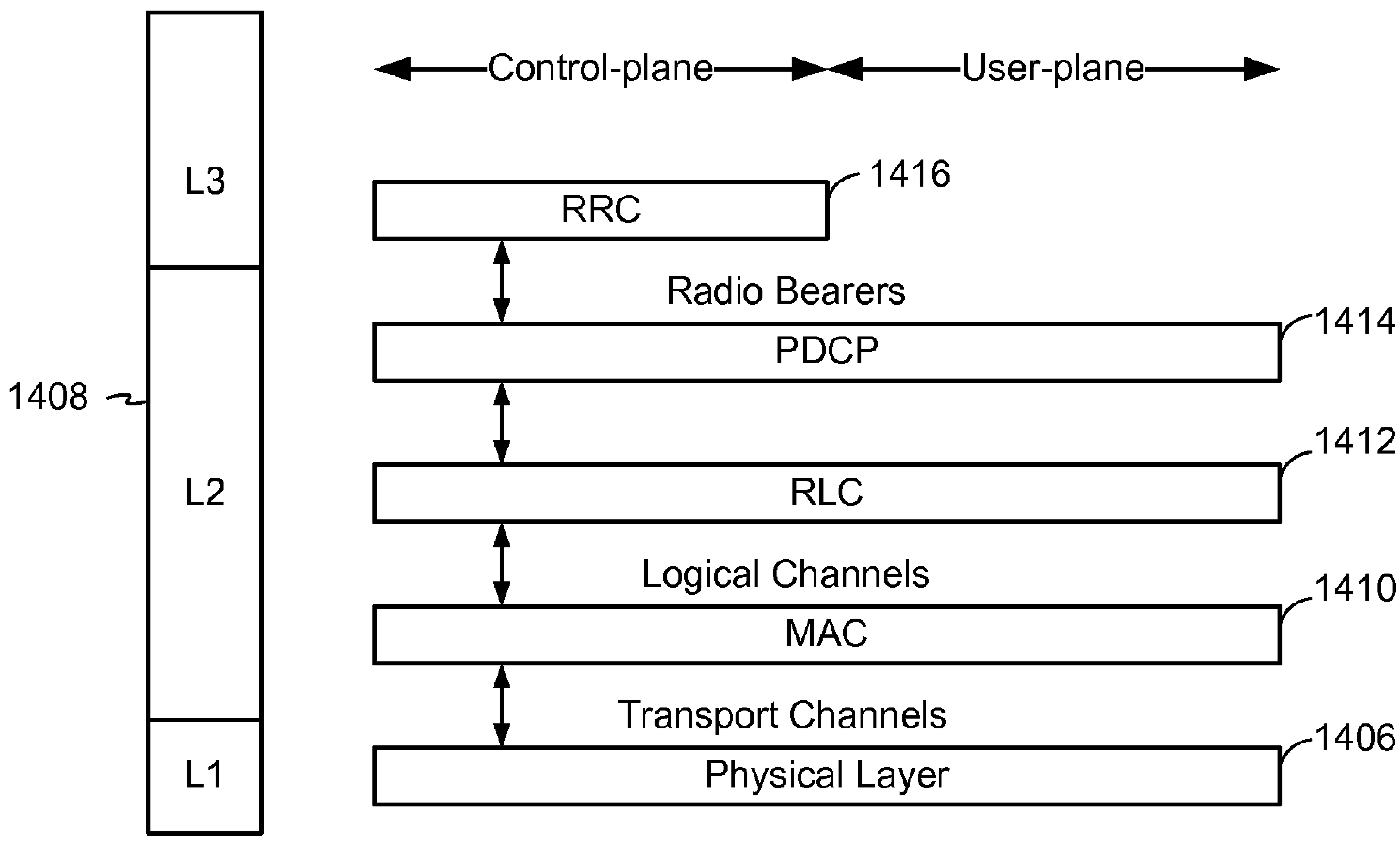

Control-plane
User-plane
L3
L2
L1
1408
RRC
1416
Radio Bearers
PDCP
1414
RLC
1412
Logical Channels
MAC
1410
Transport Channels
Physical Layer
1406

FIG. 14

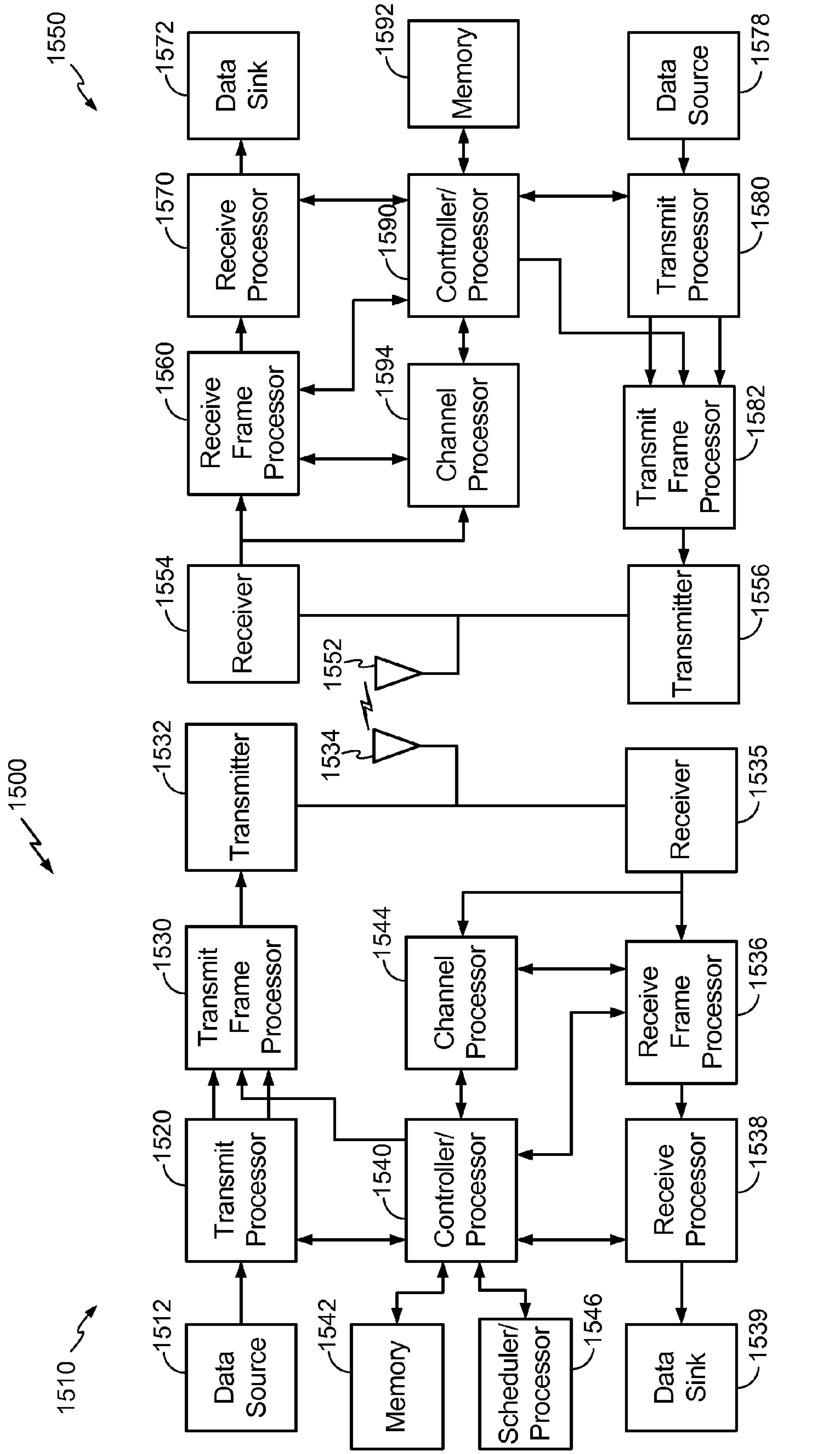

1500
1510
1512
Data Source
1520
Transmit Processor
1530
Transmit Frame Processor
1532
Transmitter
1534
1535
Receiver
1536
Receive Frame Processor
1538
Receive Processor
1539
Data Sink
1540
Controller/ Processor
1542
Memory
1544
Channel Processor
1546
Scheduler/ Processor
1550
1552
1554
Receiver
1556
Transmitter
1560
Receive Frame Processor
1570
Receive Processor
1572
Data Sink
1578
Data Source
1580
Transmit Processor
1582
Transmit Frame Processor
1590
Controller/ Processor
1592
Memory
1594
Channel Processor

FIG. 15

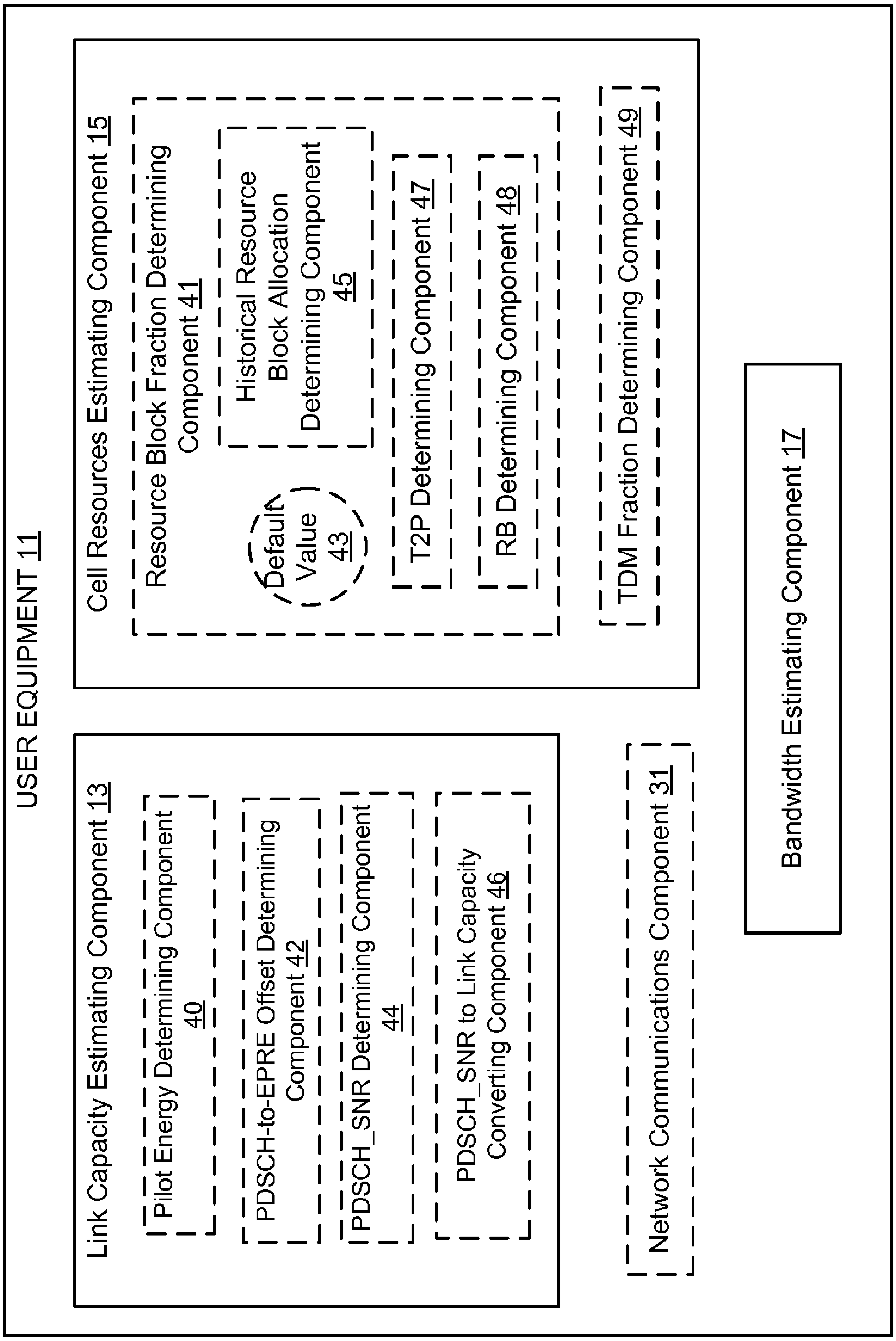

USER EQUIPMENT 11
Link Capacity Estimating Component 13
Pilot Energy Determining Component 40
PDSCH-to-EPRE Offset Determining Component 42
PDSCH_SNR Determining Component 44
PDSCH_SNR to Link Capacity Converting Component 46
Cell Resources Estimating Component 15
Resource Block Fraction Determining Component 41
Default Value 43
Historical Resource Block Allocation Determining Component 45
T2P Determining Component 47
RB Determining Component 48
TDM Fraction Determining Component 49
Network Communications Component 31
Bandwidth Estimating Component 17

FIG. 16

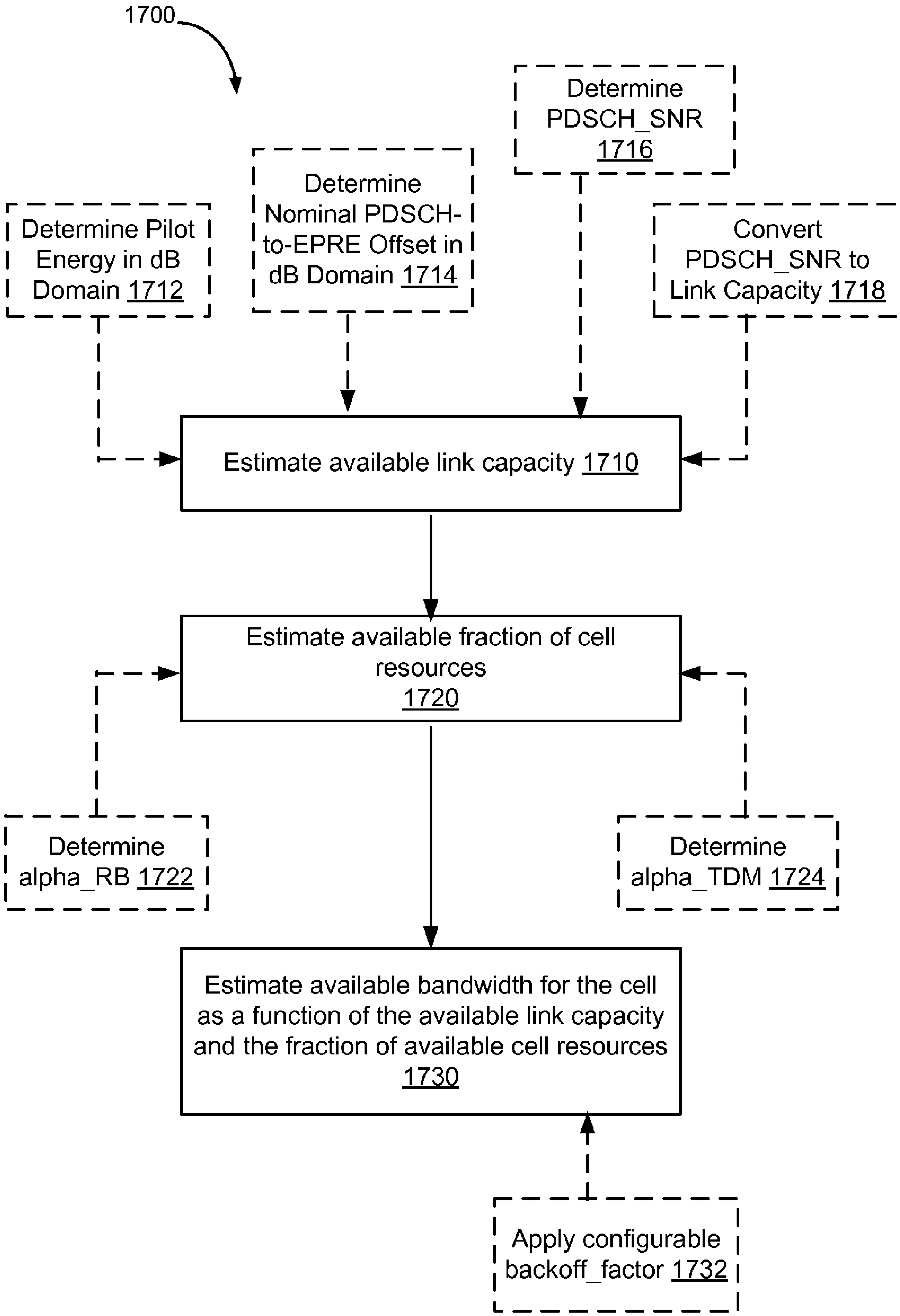

1700
Determine PDSCH_SNR 1716
Determine Nominal PDSCH-to-EPRE Offset in dB Domain 1714
Determine Pilot Energy in dB Domain 1712
Convert PDSCH_SNR to Link Capacity 1718
Estimate available link capacity 1710
Estimate available fraction of cell resources 1720
Determine alpha_RB 1722
Determine alpha_TDM 1724
Estimate available bandwidth for the cell as a function of the available link capacity and the fraction of available cell resources 1730
Apply configurable backoff_factor 1732

FIG. 17

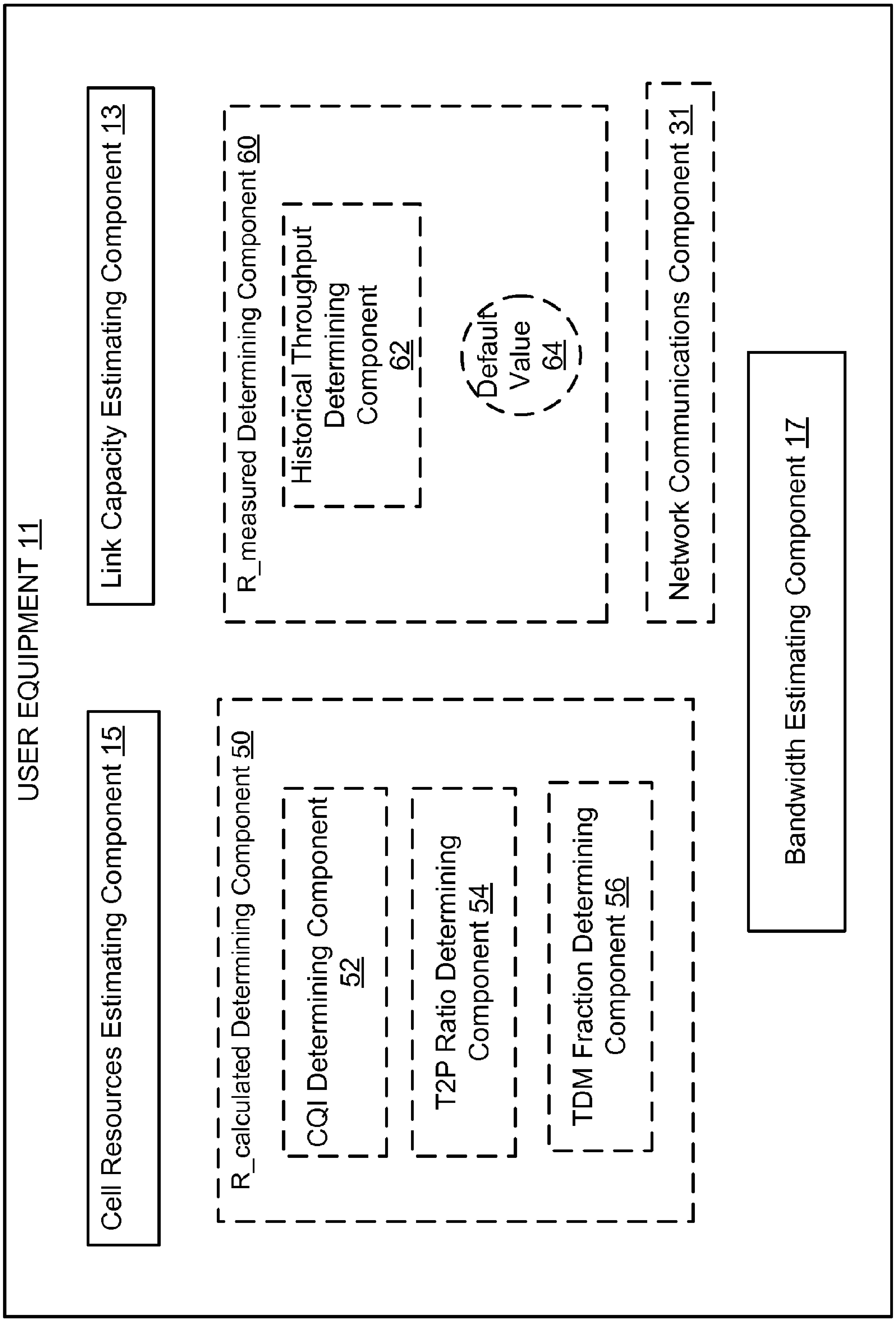

USER EQUIPMENT 11
Link Capacity Estimating Component 13
Cell Resources Estimating Component 15
R_measured Determining Component 60
Historical Throughput Determining Component 62
Default Value 64
Network Communications Component 31
R_calculated Determining Component 50
CQI Determining Component 52
T2P Ratio Determining Component 54
TDM Fraction Determining Component 56
Bandwidth Estimating Component 17

FIG. 18

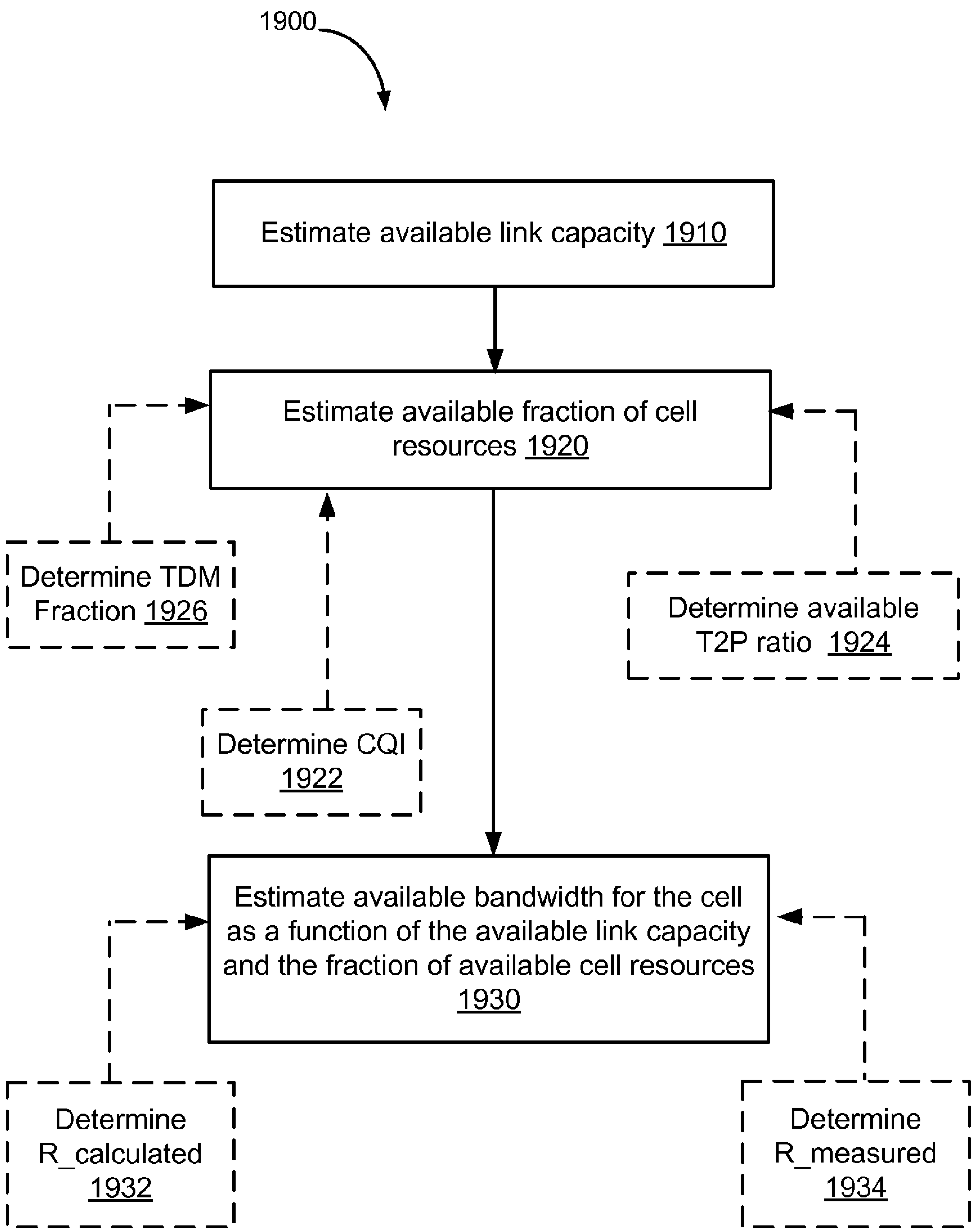

1900
Estimate available link capacity 1910
Estimate available fraction of cell resources 1920
Determine TDM Fraction 1926
Determine CQI 1922
Determine available T2P ratio 1924
Estimate available bandwidth for the cell as a function of the available link capacity and the fraction of available cell resources 1930
Determine R_calculated 1932
Determine R_measured 1934

FIG. 19

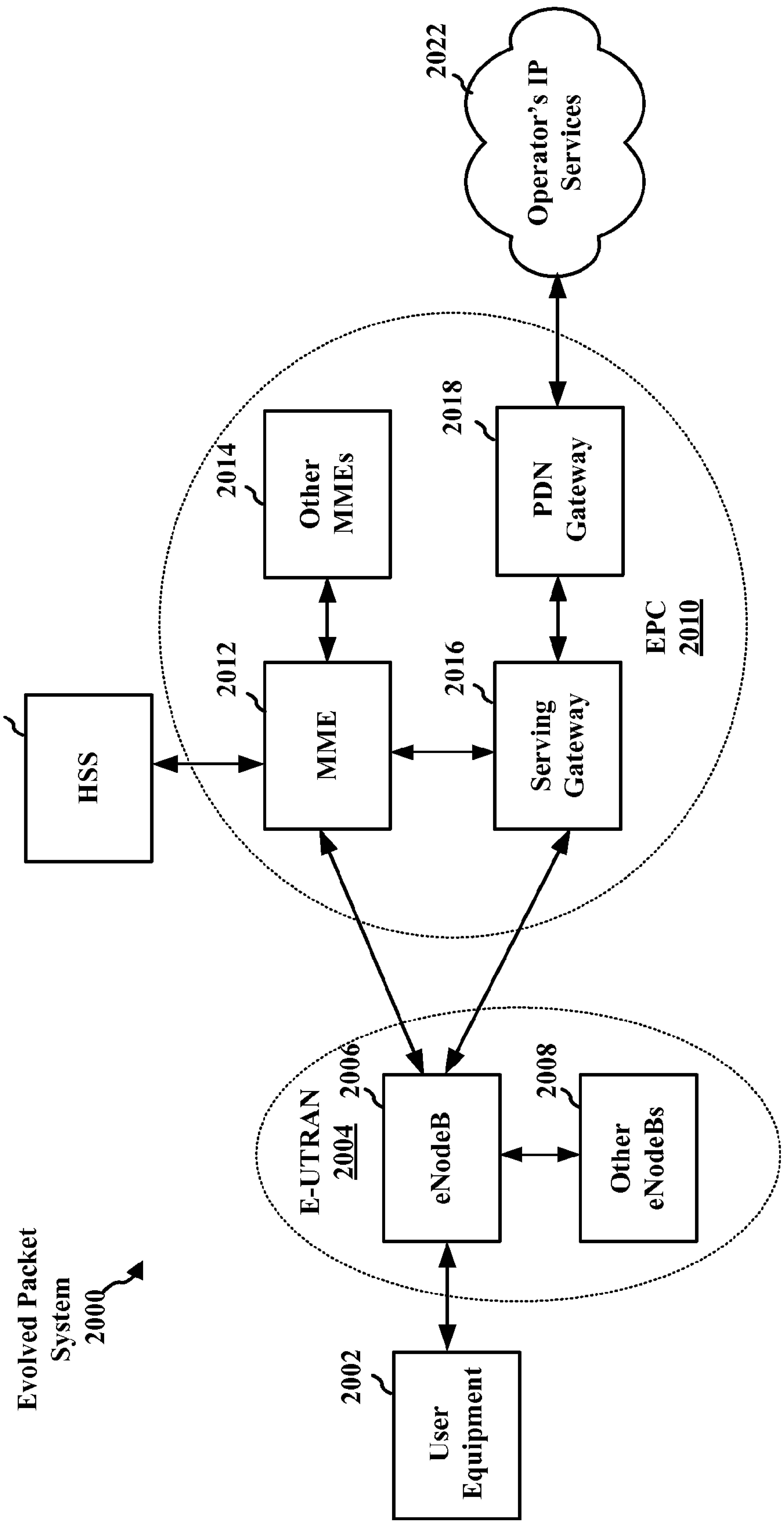

Evolved Packet System 2000
User Equipment
2002
E-UTRAN 2004
eNodeB
2006
Other eNodeBs
2008
HSS
2020
MME
2012
Other MMEs
2014
Serving Gateway
2016
PDN Gateway
2018
EPC 2010
Operator's IP Services
2022

FIG. 20

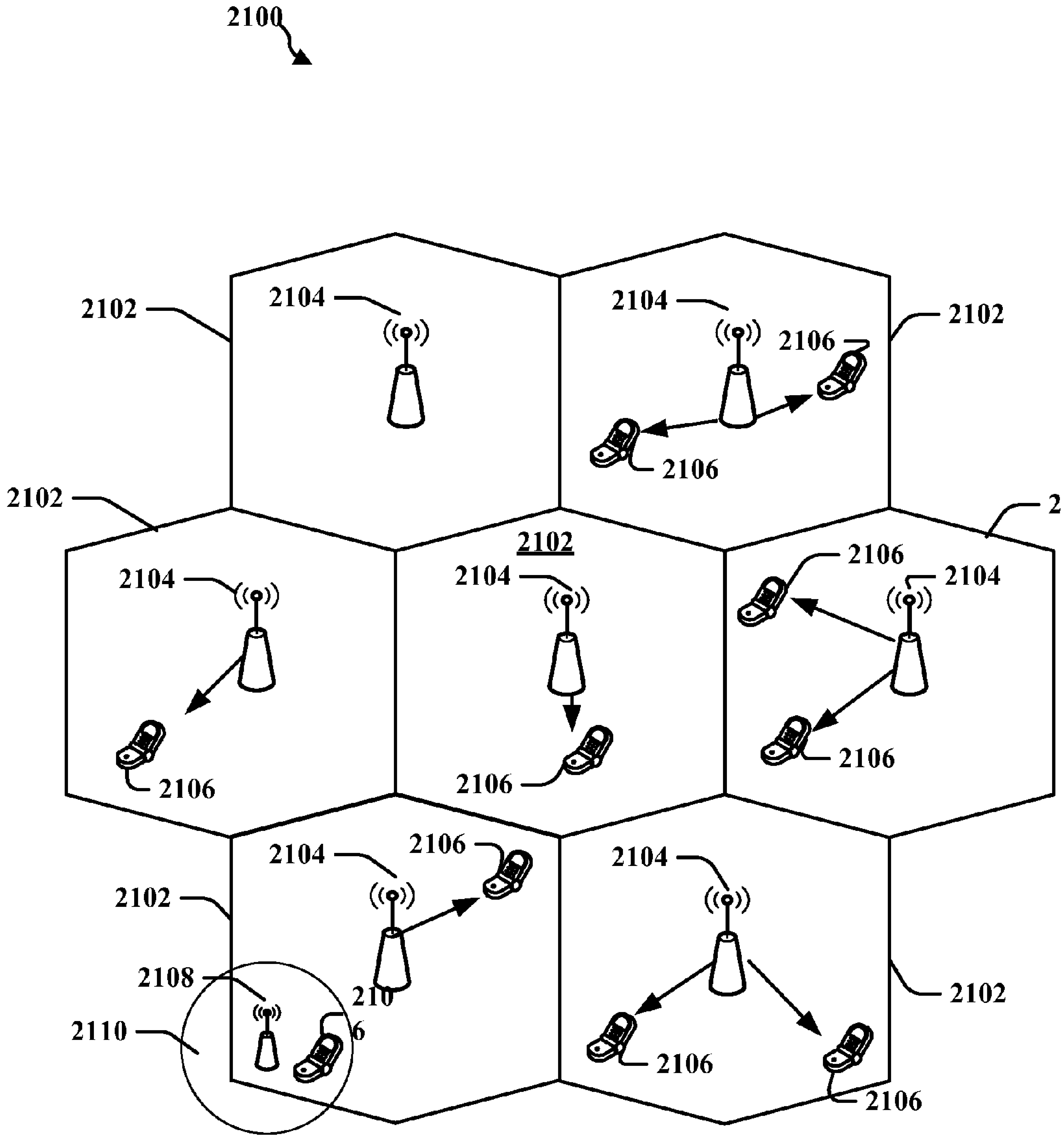
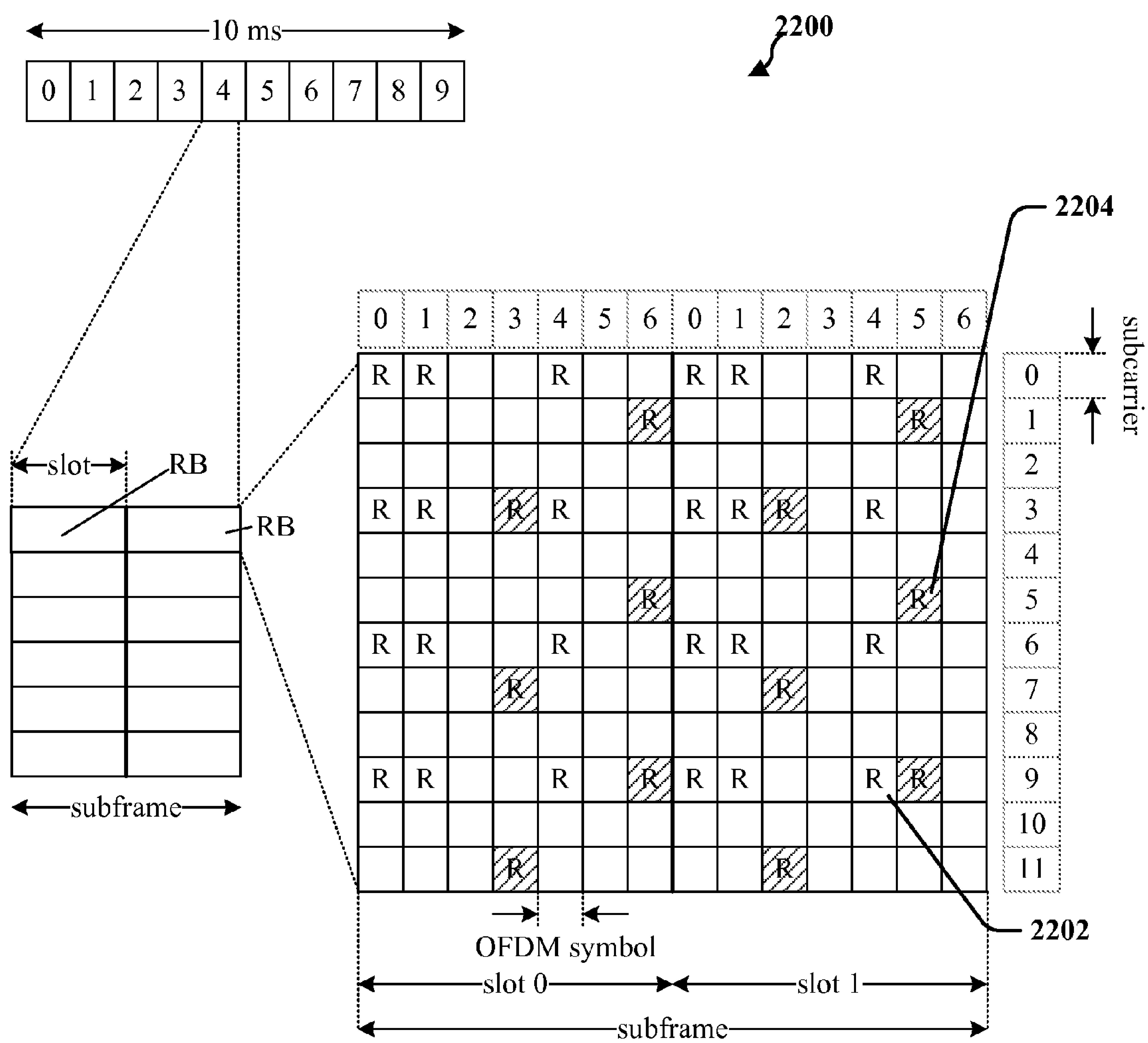

2100
2102
2104
2106
2102
2104
2106
2102
2104
2106
2102
2104
2106
2102
2104
2106
2102
2104
2106
2102
2104
2106
2108
2110
2102
2104
2106
2106

FIG. 21



2200
10 ms
0 1 2 3 4 5 6 7 8 9
slot
RB
RB
subframe
2204
0 1 2 3 4 5 6 0 1 2 3 4 5 6
R
subcarrier
0 1 2 3 4 5 6 7 8 9 10 11
OFDM symbol
slot 0
slot 1
subframe
2202

FIG. 22

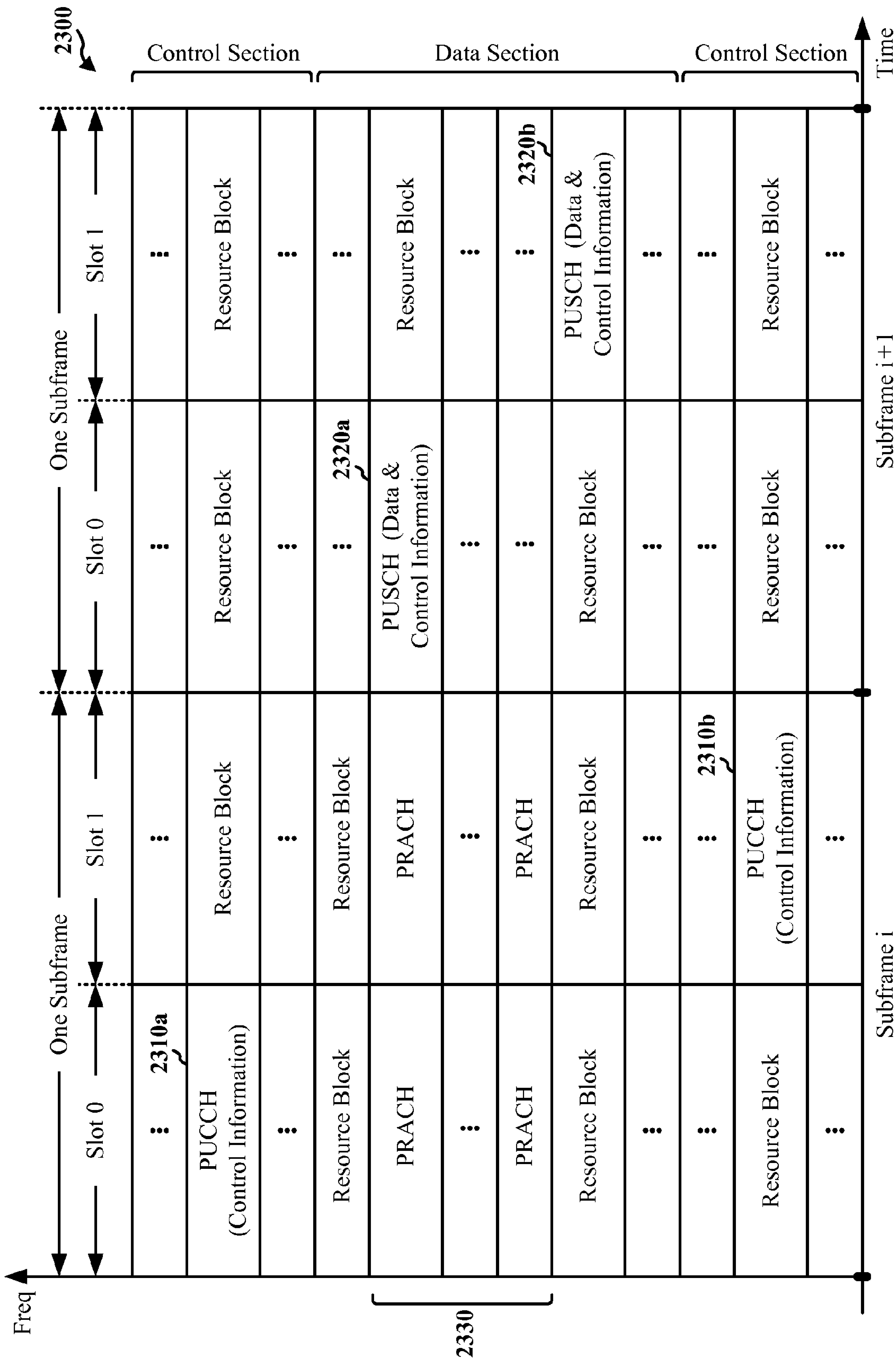

2300
Control Section
Data Section
Control Section
Time
Freq
One Subframe
One Subframe
Slot 0
Slot 1
Slot 0
Slot 1
PUCCH (Control Information)
2310a
2310b
PUCCH (Control Information)
PUSCH (Data & Control Information)
2320a
2320b
PUSCH (Data & Control Information)
Resource Block
PRACH
2330
Subframe i
Subframe i+1

FIG. 23

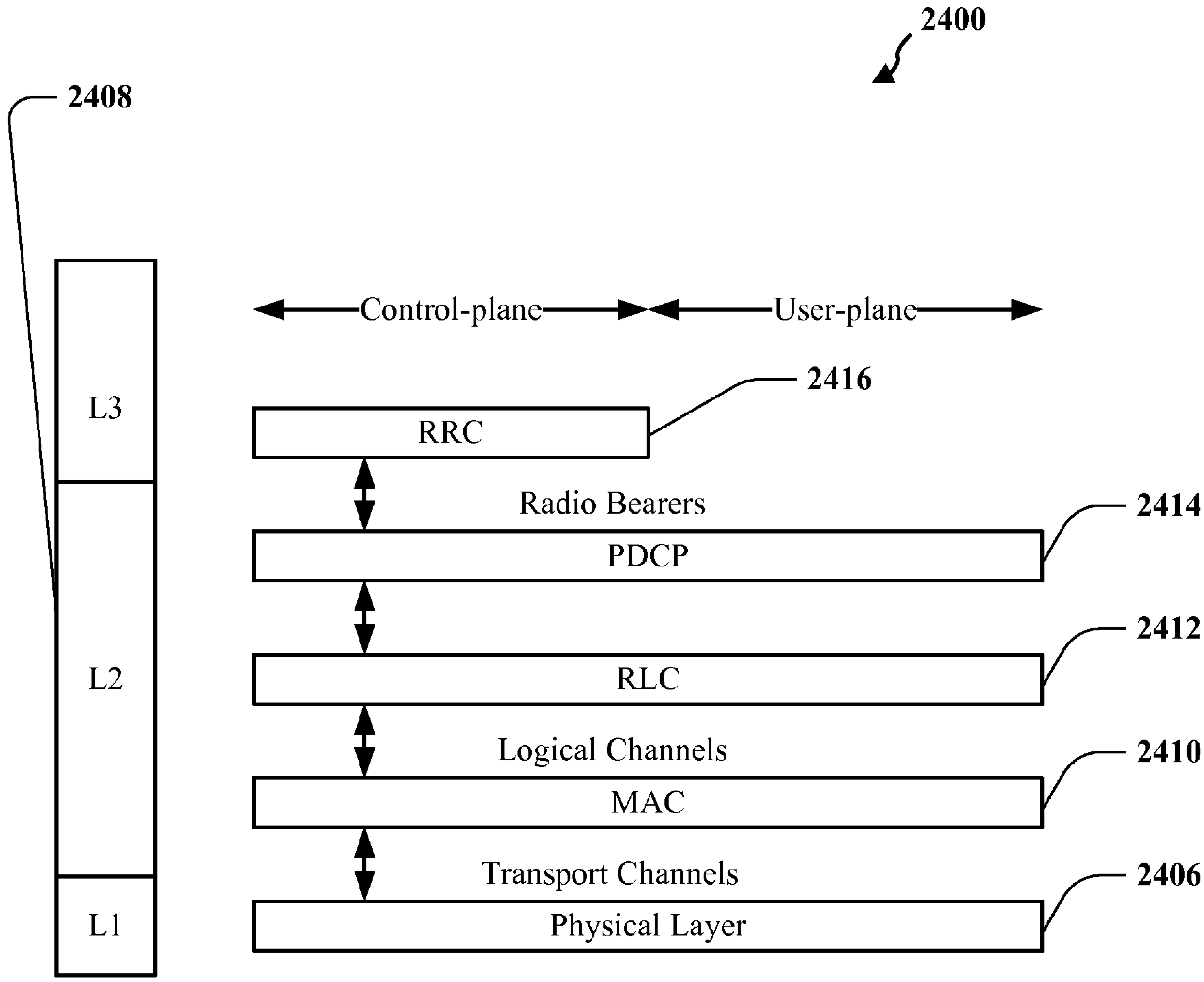

2400
2408
Control-plane
User-plane
2416
L3
RRC
Radio Bearers
2414
PDCP
2412
L2
RLC
Logical Channels
2410
MAC
Transport Channels
2406
L1
Physical Layer

FIG. 24

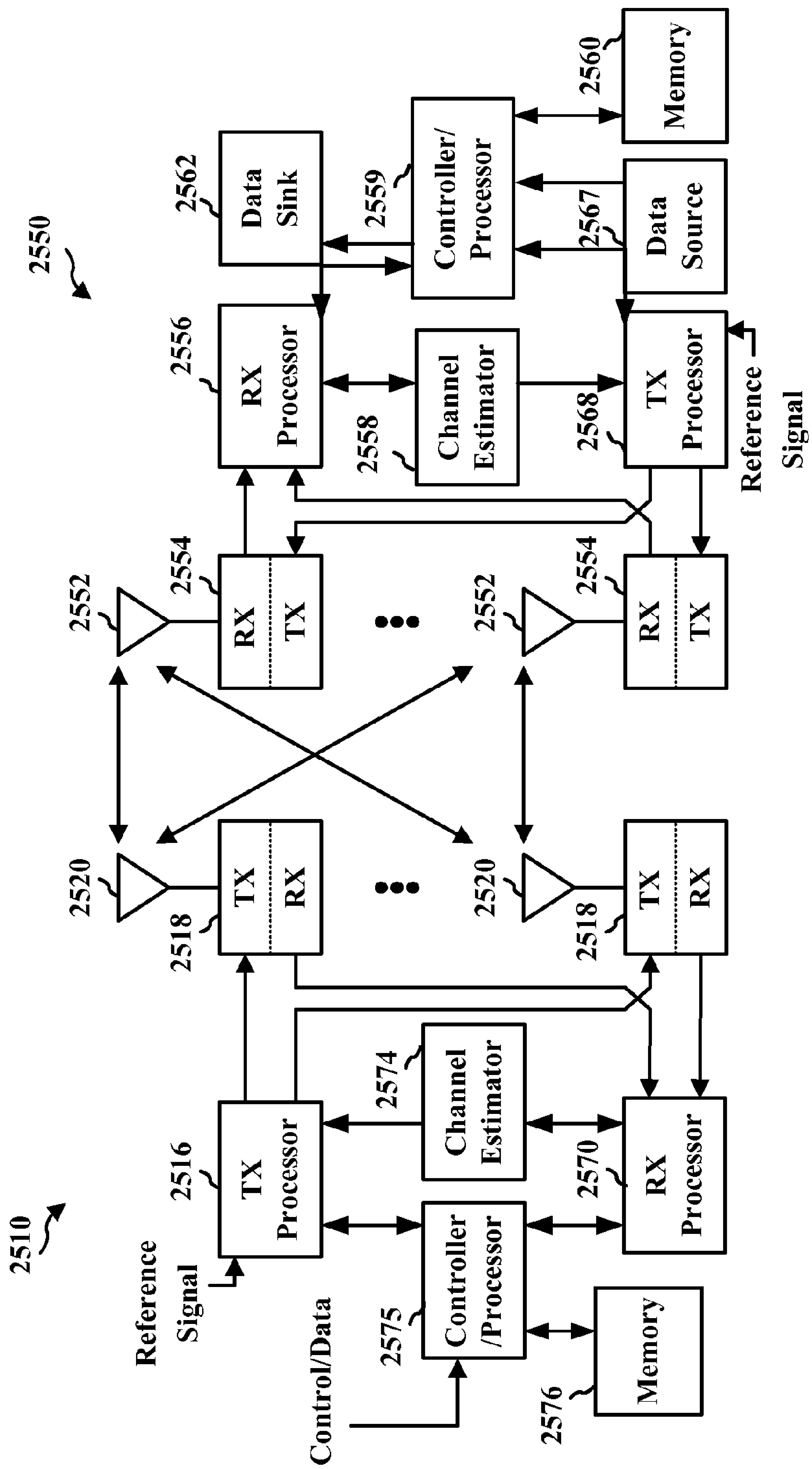

2510
2550
Reference Signal
2516
TX Processor
Control/Data
2575
Controller /Processor
2576
Memory
2574
Channel Estimator
2570
RX Processor
2518
TX
RX
2520
2552
2554
RX
TX
2556
RX Processor
2558
Channel Estimator
2568
TX Processor
Reference Signal
2562
Data Sink
2559
Controller/ Processor
2560
Memory
2567
Data Source

FIG. 25

METHOD AND APPARATUS FOR AVAILABLE BANDWIDTH ESTIMATION BY A USER EQUIPMENT IN IDLE AND/OR CONNECTED MODE

CLAIM OF PRIORITY UNDER 35 U.S.C. §119

The present Application for patent claims priority to Provisional Application No. 61/676,671 entitled "METHOD AND APPARATUS FOR DETERMINING AVAILABLE TRAFFIC-TO-PILOT RATIO OF A CELL", filed Jul. 27, 2012; Provisional Application No. 61/756,967 entitled "METHOD AND APPARATUS FOR AVAILABLE BANDWIDTH ESTIMATION", filed Jan. 25, 2013; and Provisional Application No. 61/807,127 entitled "METHOD AND APPARATUS FOR AVAILABLE BANDWIDTH ESTIMATION IN AN LTE SYSTEM" filed Apr. 1, 2013, each of which is assigned to the assignee hereof and each of which is hereby expressly incorporated by reference herein.

BACKGROUND

1. Field

Aspects of the present disclosure relate generally to wireless communication systems, and more particularly to estimating available bandwidth in a wireless network.

2. Background

Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency divisional multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level.

An example of a telecommunication standard is Universal Mobile Telecommunications System (UMTS). UMTS is a third generation mobile cellular system for networks based on the Global System for Mobile Communications (GSM) standard. UMTS was developed and maintained by the 3rd Generation Partnership Project (3GPP), and is a component of the International Telecommunications Union IMT-2000 standard set and compares with the CDMA2000 standard set for networks based on the competing cdmaOne technology. UMTS uses wideband code division multiple access (W-CDMA) radio access technology to offer greater spectral efficiency and bandwidth to mobile network operators. UMTS specifies a complete network system which uses, covering the radio access network (UMTS Terrestrial Radio Access Network, or UTRAN), the core network (Mobile Application Part, or MAP) and the authentication of users via SIM (subscriber identity module cards).

Another example of a telecommunication standard is Long Term Evolution (LTE). LTE is a set of enhancements to the UMTS mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lower costs, improve services, make use of new spectrum, and better integrate with other open standards using OFDMA on the downlink (DL), SC-FDMA on the uplink (UL), and multiple-input multiple-output (MIMO) antenna technology. However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in LTE technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

Mobile terminals, or user equipment (UE), can communicate with one or more base stations in an active communication mode, or a more conservative communication mode, such as idle mode where the UE powers down its transceiver during some time intervals to save power. In idle mode, for example, the UE can power up its transceiver during defined paging intervals to receive paging signals from the base station(s), or to establish an active communication mode connection with the base station(s). The UE can switch communications among base stations when in an active mode, e.g., via a handover process, or when in an idle mode, e.g., via a cell reselection procedure. Selection or reselection of base stations or related cells is typically based on a signal strength in a candidate cell; however, with the addition of user-deployable base stations (e.g., femto nodes, pico nodes, or the like), there can be multiple cells with sufficient signal strength to adequately serve a UE. In addition, a UE may obtain wireless services by communicating with a network (e.g., UMTS or LTE) or a nearby wireless local area network (e.g., WiFi). In some instances, LTE and/or UMTS may prove to be a better network (e.g., it may provide service to a UE that is faster, with greater bandwidth, providing greater throughput, or some other quality measurement), while in other instances, or at other times, WiFi may prove to be the better network.

As such, it is desirable to determine metrics that may allow a UE to select the better network as between LTE and/or UMTS and WiFi at a given point in time.

SUMMARY

The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

In an aspect, a method for determining available downlink bandwidth is described. The method may include estimating an available link capacity of a cell for a user equipment. The method may include estimating an available fraction of cell resources for the user equipment. The method may include estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources.

In an aspect, a computer program product for determining available downlink bandwidth is described. The computer program product includes a computer-readable medium comprising code. The code may cause a computer to estimate an available link capacity of a cell for a user equipment. The code may cause a computer to estimate an available fraction of cell resources for the user equipment. The code may cause a computer to estimate available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources.

In an aspect, an apparatus for determining available downlink bandwidth is described. The apparatus may include means for estimating an available link capacity of a cell for a user equipment. The apparatus may include means for estimating an available fraction of cell resources for the user equipment. The apparatus may include means for estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources.

In an aspect, an apparatus for determining available downlink bandwidth is described. The apparatus may include at least one memory. The apparatus may include a link capacity estimating component for estimating an available link capacity of a cell for a user equipment. The apparatus may include a cell resources estimating component for estimating an available fraction of cell resources for the user equipment. The apparatus may include a bandwidth estimating component for estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources.

To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed aspects will hereinafter be described in conjunction with the appended drawings, provided to illustrate and not to limit the disclosed aspects, wherein like designations denote like elements, and in which:

FIG. **1** is a block diagram of an aspect of a system, including a user equipment (UE) in communication with cells, for determining available downlink bandwidth of a cell;

FIG. **2** is a flow chart of a method for determining available downlink bandwidth of a cell;

FIG. **3** is a block diagram of aspects of a UE in an idle mode for determining available downlink bandwidth at a cell operating according to a Universal Mobile Telecommunications System (UMTS) standard;

FIG. **4** is a block diagram of additional aspects of a UE in an idle mode for determining available downlink bandwidth at a cell operating according to UMTS;

FIG. **5** is a flowchart showing a method for determining available downlink bandwidth of a cell operating according to UMTS by a UE in an idle mode;

FIG. **6** is a flowchart of additional aspects of the method of FIG. **5**;

FIG. **7** is a block diagram of one aspect of a system, including a UE in communication with cells, for determining available traffic-to-pilot (T2P) ratio at a cell operating according to UMTS when the UE is in an idle mode;

FIG. **8** is a flowchart of a method for determining available T2P ratio at a cell operating according to UMTS when the UE is in an idle mode;

FIG. **9** is a block diagram of aspects of a UE in a connected mode for determining available downlink bandwidth at a cell operating according to UMTS;

FIG. **10** is a flowchart showing a method for determining available downlink bandwidth of a cell operating according to UMTS by a UE in a connected mode;

FIG. **11** is a block diagram illustrating an example of a hardware implementation for the UE employing a processing system associated with aspects of FIGS. **1-10**;

FIG. **12** is a block diagram illustrating an example of a telecommunications system associated with aspects of FIGS. **1-10**;

FIG. **13** is a block diagram illustrating an example of an access network associated with aspects of FIGS. **1-10**;

FIG. **14** is a block diagram illustrating an example of a radio protocol architecture for the user and control plane implemented by components of the systems associated with aspects of FIGS. **1-10**;

FIG. **15** is a block diagram illustrating an example of a Node B in communication with a UE in a telecommunications system, including aspects associated with aspects of FIGS. **1-10**.

FIG. **16** is a block diagram of aspects of a UE in an idle mode in communication with a cell operating according to LTE;

FIG. **17** is a flow chart of a method for determining available downlink bandwidth of a cell operating according to LTE when a UE is in an idle mode;

FIG. **18** is a block diagram of aspects of a UE in a connected mode in communication with a cell operating according to LTE;

FIG. **19** is a flow chart of a method for determining available downlink bandwidth of a cell operating according to LTE when a UE is in a connected mode;

FIG. **20** is a block diagram illustrating an example of a network architecture associated with aspects of FIGS. **16-19**;

FIG. **21** is a block diagram illustrating an example of an access network associated with aspects of FIGS. **16-19**;

FIG. **22** is a block diagram illustrating an example of a DL frame structure in LTE;

FIG. **23** is a block diagram illustrating an example of a UL frame structure in LTE;

FIG. **24** is a block diagram illustrating an example of a radio protocol architecture for the user and control planes; and

FIG. **25** is a block diagram illustrating an example of an evolved Node B and UE, associated with aspects of FIGS. **16-19**, in an access network.

DETAILED DESCRIPTION

Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It may be evident, however, that such aspect(s) may be practiced without these specific details.

The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

The present apparatus and methods include various aspects related to determining available downlink bandwidth of a cell. In an aspect, the cell may be operating according to a Universal Mobile Telecommunications System (UMTS) communication standard. In another aspect, the cell may be operating according to a Long Term Evolution (LTE) communication standard.

The apparatus and methods described herein may be used, for example, at a time when the UE has a packet to transmit, or at a time when a new traffic flow starts at the UE, or as a result of a periodic evaluation or in response to some conditions changing (for instance backhaul or radio conditions) in an initial network registration or call establishment process, a reselection procedure of the UE, or in a handover procedure of the UE in connected mode with an active call. An available downlink bandwidth may be determined by the UE while it is in idle mode and/or while it is in a connected mode.

In an aspect, a UE may be connected to a cell operating according to a Universal Mobile Telecommunications System (UMTS) communication standard. In such an aspect, the available downlink bandwidth of the cell can be estimated as a function of an estimated available link capacity and an estimated fraction of available cell resources while the UE is in the idle mode. The estimated available link capacity of the cell may be based on a signal-to-noise ratio (SNR) of a signal from the cell. For example, an SNR-related parameter may be determined and, based on the SNR-related parameter, a corresponding link capacity (or supported rate) may be determined based on accessing a rate look-up table, or executing an algorithm or function.

Further, the estimated available fraction of cell resources may be based on an available number of codes for the cell. Optionally, the available downlink bandwidth of a cell can be further estimated as a function of an available traffic-to-pilot (T2P) ratio (also referred to herein as T2Pavailable) for the cell, and/or as a function of a measurement power offset (MPO) for the cell. For example, in various aspects, one or both of the available T2P ratio and MPO may be used to determine one or both of the estimated available link capacity and the estimated available fraction of cell resources. Further, in an aspect, a time-domain multiplexing (TDM) fraction also may be used to estimate the available downlink bandwidth of the cell. Thus, the present apparatus and methods can allow for evaluation of the cell for a variety of purposes relating to network communications.

Additionally, and in an aspect, a UE may determine available downlink traffic-to-pilot (T2P) ratio of the cell, which may allow for evaluating the cell for network communications. In one example, the UE can determine whether to handover communications from a cell based on an available T2P ratio. For example, the available T2P ratio can be estimated based on signal energy measured over a period of time. The signal energy can include that of a serving cell, neighboring cells, a total received energy, or the like Over a period of time, such measurements can be used to determine a T2P used and a T2P maximum over the period of time. In one example, the available T2P can then be estimated by subtracting a current T2P from the maximum T2P.

In an aspect, the estimated available link capacity of a cell may be calculated as: Ec/Nt=Ecp/Nt+T2Pavailable. In another aspect, the estimated available link capacity of a cell may be calculated as: Ec/Nt=Ecp/Nt+MPO.

A supported rate corresponding to the calculated Ec/Nt may be determined based on an accessing a rate look-up table, or executing an algorithm or function. As such, the total bandwidth may be determined corresponding to a total number of codes used by the cell for the supportable rate. The total bandwidth may be scaled based on the available number of codes, the ratio of T2Pavailable/MPO, and/or the TDM fraction to determine the estimated available bandwidth.

In another aspect, the available downlink bandwidth of a cell can be estimated as a function of an estimated available link capacity and an estimated fraction of available cell resources while the UE is in the connected mode. For example, the UE may estimate an available fraction of cell resources for the UE based on an available number of codes for the cell. For example, a UE may estimate an available link capacity of a cell for a UE based on a channel quality index generated at the UE. More particularly, and in an aspect, the UE may estimate available link capacity by determining a supportable rate based on the channel quality index. The UE may determine a partial bandwidth corresponding to a total number of codes used by the cell for the supportable rate. The UE may scale the partial bandwidth based on at least one of an average served number of codes, a time-division multiplexing (TDM) fraction, and a ratio of T2Pavailable to MPO. In an aspect, the UE may estimate available bandwidth of the cell as a function of the estimated available link capacity, the estimated available fraction of cell resources (and/or the scaled partial bandwidth), and the connected mode throughput observed over the one or more past scheduling events.

In an additional aspect, the UE may be configured to determine an available T2P ratio, MPO, and TDM fraction for the cell. As such, the UE may be configured to estimate the available link capacity and/or the available fraction of cell resources based on the T2P ratio, the MPO, TDM fraction, and/or the channel quality index.

In an aspect, the available link capacity may be estimated by determining a supportable rate based on the channel quality index, determining a partial bandwidth corresponding to a total number of codes used by the cell for the supportable rate, scaling the partial bandwidth based on at least one of an average served number of codes, a time-division multiplexing (TDM) fraction, and a ratio of T2Pavailable/MPO to determine the partial available bandwidth, and combining the partial bandwidth to an observed connected mode throughput over one or more past scheduling events to determine the total available bandwidth.

In an aspect, a UE may be communicating with a cell operating according to a Long Term Evolution (LTE) communication standard.

In such aspect, when a UE is in an idle mode, an available downlink (DL) bandwidth of a communication link with a base station operating according to an LTE standard (also referred to as an eNodeB) may be estimated as a function of an estimated available link capacity (link_capacity) and an estimated fraction of available cell resources (alpha or α), for example.

In accordance with this exemplary aspect, an estimated available link capacity (link_capacity), which may be similar to a Channel Quality Indicator (CQI) generated at the UE in connected mode, may be derived from information available at the UE in the idle mode. In an aspect, estimated available link capacity may be determined based on pilot energy (Ep/Nt) and a nominal Physical Downlink Shared Channel (PDSCH)-to-Energy Per Resource Element (EPRE) offset. For example, the sum of Ep/Nt (in the decibel domain) and PDSCH-to-EPRE offset (in the decibel domain) may provide a pilot tone signal-to-noise ratio (SNR) (PDSCH_SNR). The PDSCH_SNR may be converted to link capacity (e.g., a rate), in an aspect, using a CQI index-to-rate lookup table. In another aspect, the PDSCH_SNR may be converted to link capacity based on the Shannon capacity equation. In yet another aspect, a UE may be configured to map PDSCH_SNR with CQI indices while in the connected mode, which mapping could then be used by the UE in idle mode to convert the measured Reference Signal (RS) SNR to a CQI index in the idle mode. The UE may then use a CQI index-to-rate lookup table to determine an estimated link capacity (e.g., rate) based on the CQI index. In an aspect, the terms link capacity and rate may be used interchangeably to relate to an amount of data that may be supported during UE communications.

An estimated fraction of available cell resources (α) may be derived based on a function of a resource block fraction (RB) (alpha_RB) and a TDM fraction (alpha_TDM). In an aspect, the number of resource blocks (alpha_RB) may be determined based on historical data: resource blocks that were allocated to the UE in the connected mode in the recent past (e.g., over a configurable time window of T seconds) when the traffic volume was above a configurable threshold (e.g., traffic volume was at least X bits during time window T). In another aspect, and in the absence of enough history to determine the number of resource blocks, a default value may be used. For example, if the selected amount of time (e.g., the window of time T seconds) has not yet elapsed and/or if the traffic volume was not above a configurable threshold (e.g., was not at least X bits) during the window of time, the UE **11** may determine that there is not enough historical data to determine a number of resource blocks. As such, a default value may be used for the number of resource blocks. In yet another aspect, the number of resource blocks may be determined based on a total traffic-to-pilot (T2P) power transmitted from the eNodeB during a configurable window of time when traffic volume was above a configurable threshold. The resource block fraction (alpha_RB) may be determined based on available resource blocks divided by total resource blocks (assuming no traffic from other users).

The TDM fraction (alpha_TDM), which provides information related to resource blocks provided to the UE from the eNodeB for every one out of a configurable number N of time transmission intervals (TTI), may be determined based on historical data: a number of resource blocks provided for every 1/N TTIs over a configurable time window when traffic volume was above a configurable threshold. The TDM fraction (alpha_TDM) may be an average of the historical data.

As such, and in an aspect, the estimated fraction of available cell resources (α) may be determined by alpha_RB*alpha_TDM.

In another aspect, a fraction of available cell resources may be provided to the UE by at least one network entity. For example, the estimated fraction of available cell resources may be provided to the UE by a serving eNodeB, a network node, a server, one or more other UEs (e.g., the value may be crowd-sourced), or any combination thereof. In such an aspect, the UE may not have to perform an estimation but, rather, may use the provided value. In yet another aspect, the at least one network entity may provide alpha_RB and alpha_TDM to the UE, such that the UE may estimate a fraction of available cell resources (α) as a function of alpha_RB and alpha_TDM as described herein.

To ensure the estimate of available downlink (DL) bandwidth is conservative (e.g., the estimate may be a lower bound), a configurable backoff_factor, or offset, may be applied to the function link_capacity (or rate)*α.

In another aspect, when a UE is in the connected mode, the available DL bandwidth may be estimated based on a rate (or link capacity) estimate in connected mode (R_calculated) and a measured throughput in connected mode (R_measured). R_calculated may be determined based on α*link_capacity (or rate). An estimated fraction of available cell resources (α) may be determined in a manner similar to that described herein for a UE in idle mode; however, CQI may be used instead of a derived ratio of pilot energy (Ep) to noise-plus-interference ratio (Nt) and the rate may be adjusted based on an available traffic-to-pilot (T2P) ratio and the TDM fraction. The link_capacity may be determined based on the CQI, which is available to the UE in connected mode. R_measured may be determined based on historical data: throughput measured at the UE in connected mode during a configurable time window.

When an offered load for the UE is small, the connected mode estimate of available DL bandwidth may be based more heavily on R_calculated. When an offered load is large, the connected mode estimate of available DL bandwidth may be based more heavily on R_measured.

Referring to FIG. **1**, in one aspect, a wireless communication system **10** includes a UE **11** for communicating with one or more nodes, such as serving node **14**, to receive wireless network access. For example, the serving node **14** and a neighboring node **16** can each be substantially any access point, such as a Node B (e.g., a macro node, pico node, or femto node), a mobile base station, a relay node, a UE (e.g., communicating in peer-to-peer or ad-hoc mode with UE **11**), a portion thereof, and/or the like. Moreover, serving node **14** and neighboring node **16** can represent different cells provided by a single base station. In an aspect, serving node **14** and neighboring node **16** may be operating according to a Long Term Evolution (LTE) communication standard. In another aspect, serving node **14** and neighboring node **16** may be operating according to a Universal Mobile Telecommunications System (UMTS) communication standard.

In addition, UE **11** can be a mobile or stationary terminal, a modem (or other tethered device), a portion thereof, or the like The UE **11** can function in one of an idle mode or a connected mode at any given time.

In an aspect, UE **11** includes a link capacity estimating component **13** for estimating an available link capacity of a cell, such as serving node **14** or neighboring node **16**. Further, UE **11** includes a cell resources estimating component **15** for estimating an available fraction of cell resources that may be used by UE **11**. Additionally, UE **11** includes a bandwidth estimating component **17** for estimating an available bandwidth of the cell as a function of the estimated available link capacity and the estimated fraction of available cell resources.

Referring to FIG. **2**, a method **200** may be used to estimate an available bandwidth of a cell (e.g., serving node **14**) for UE **11**. UE **11** and/or bandwidth estimating component **17**, in communication with link capacity estimating component **13** and cell resources estimating component **15**, may perform aspects of method **200** while in an idle mode or in a connected mode.

At **210**, the method **200** includes estimating an available link capacity of a cell for a user equipment. For example, link capacity estimating component **13** may be configured to estimate an available link capacity for UE **11**. As noted above, UE **11** may use various mechanisms for estimating available link capacity while UE **11** is in an idle mode and/or connected mode, and when UE **11** is associated with a UMTS or LTE system.

For example, UE **11** may determine a signal-to-noise ratio (SNR), or SNR-related parameter, of a signal from the serving node **14** and then may estimate the available link capacity by, for example, determining a corresponding link capacity (or supported rate) for the SNR and/or SNR-related parameter based on accessing a rate look-up table, or executing an algorithm or function. In addition or alternatively, as noted above, UE **11** may determine a traffic-to-pilot (T2P) ratio and/or a measurement power offset (MPO) for the serving node **14** and use these determined value(s) to estimate the link capacity, such as discussed above. For example, UE **11** may estimate the available link capacity based on Ep/Nt and a nominal PDSCH-to-EPRE, such as discussed above.

It should be noted that these are but some exemplary mechanisms that UE **11** may use to estimate the available link capacity, and in other implementations other mechanisms may be used.

At **220**, the method **200** includes estimating an available fraction of cell resources for the user equipment. For example, cell resources estimating component **15** may be configured to estimate an available fraction of cell resources for UE **11**. For example, UE **11** may be configured to estimate an available fraction of cell resources based on an available T2P ratio, TDM fraction, channel quality index (CQI) and/or MPO. Additionally, or alternatively, UE **11** may be configured to estimate an available fraction of cell resources based on a resource block fraction (alpha_RB) and a Time-Domain Multiplexing (TDM) fraction (alpha_TDM).

In an aspect, an estimate of available fraction of cell resources, may be provided to the UE **11** by a network entity.

At **230**, the method **200** includes estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources. For example, bandwidth estimating component **17** may be configured to estimate available bandwidth of the cell for UE **11**.

In an aspect, serving node **14** and neighboring node **16** may be operating according to a Universal Mobile Telecommunications System (UMTS) communication standard. Such aspect may now be described with respect to FIGS. **3**-**15**. UE **11** may be in an idle mode or a connected mode at any given time.

Referring to FIG. **3**, additional aspects of UE **11**, which may be used when UE **11** is in an idle mode and operating according to UMTS, are shown. UE **11** may include link capacity estimating component **13**, cell resources estimating component **15**, and bandwidth estimating component **17**, as described herein with respect to FIG. **1**. In an aspect, and optionally, UE **11** also may include a traffic-to-pilot (T2P) ratio determining component **19** for estimating a T2P ratio of a cell, and/or a measurement power offset (MPO) determining component **21** for estimating an MPO for a cell, where the available bandwidth of the cell may further be a function of the T2P ratio and/or the MPO. The additional, optional, components, which are not shown as part of UE **11** in FIG. **1**, may optionally be used by UE **11** when operating in an idle mode and according to UMTS.

Referring to FIG. **4**, additional aspects of UE **11**, which may be used when UE **11** is in an idle mode and operating according to LTE, are shown. More particularly, FIG. **4** shows additional, detailed aspects of UE **11** as shown in, and described with respect to, FIG. **3**.

In an aspect, and optionally, UE **11** and/or link capacity estimating component **13** may include a signal energy measuring component **20** for measuring signal energy associated with one or more cells. Also, UE **11** and/or link capacity estimating component **13** may include a signal-to-interference-plus-noise (SIR) ratio determining component **23** for calculating one or more signal relative to interference ratios, such as a SIR, from the measured signal energy associated with one or more cells. The additional, optional, components shown within link capacity estimating component **13** and cell resources estimating component **15**, which are not shown as part of UE **11** in FIG. **1** or FIG. **2**, may optionally be used by UE **11** when operating in an idle mode and according to UMTS.

Further, in another optional aspect, UE **11** and/or cell resources estimating component **15** may include a rate determining component **25** for determining a supportable rate based on an SNR-related parameter. For example, cell resources estimating component **15** and/or rate determining component **25** may access a stored or remotely available rate look-up table, or execute an algorithm or function, to estimate a supported rate corresponding to the calculated SNR-related parameter, where the supported rate may be further based on a category value associated with UE **11**. For instance, the category may be one of a High-Speed Packet Access (HSPA) UE category, which may describe different characteristics, such as, for example, different High-Speed Downlink Packet Access (HSDPA) data rates for UE **11**. These HSPA categories may be used to cater to a particular one of a number of implementations of the HSDPA standard for UE **11**, which may allow for different levels of performance to be used, including a maximum HSDPA data rate. The characteristics of UE **11** can be easily communicated to the network, based on the HSPA category, allowing the network to communicate with UE **11** in a suitable manner.

Also, in this aspect, UE **11** and/or cell resources estimating component **15** may include a total bandwidth determining component **27** for determining a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. For example, cell resources estimating component **15** and/or total bandwidth determining component **27** may access a stored or remotely available rate look-up table, or execute an algorithm or function, to determine the total bandwidth that is correlated with the total number of codes used by the cell for the supportable rate.

Further, in this aspect, UE **11** and/or cell resources estimating component **15** may include a code determining component **28** for determining one or more available number of code-related metrics. For example, code determining component **28** may include an algorithm configured to determine and store the available number of codes for the cell according to one or more of: averaging a served number of codes per past scheduling event based on one or more past scheduling events; averaging a served number of codes per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold; a fixed amount of codes when the one or more past scheduling events do not meet a freshness threshold; and a given amount of codes received from at least one network entity.

In this aspect, UE **11** and/or cell resources estimating component **15** may include Time-Division Multiplexing (TDM) fraction determining component **29**, which may be configured to determine a TDM fraction according to one or more of: averaging TDM fractions per past scheduling event based on one or more past scheduling events; averaging TDM fractions per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold; determining a fixed TDM fraction when the one or more past scheduling events do not meet a freshness threshold; and receiving TDM fraction information from at least one network entity.

Additionally, in this aspect, UE **11** and/or cell resources estimating component **15** may include a scaling component **30** for scaling the total bandwidth based on one or more factors, such as one or any combination of the available number of codes, an average served number of codes, T2Pavailable, MPO, the ratio of T2Pavailable/MPO, and/or the TDM fraction, thereby defining the estimated available bandwidth.

Additionally, in a further optional aspect, UE **11** may additionally include a network communications component **31** for performing one or more network communications procedures based on the estimated available bandwidth for a cell, as determined by bandwidth estimating component **17**. For example, the network communication procedures performed by network communications component **31** may include, but are not limited to, a cell reselection procedure, a handover procedure, and/or switching from UMTS to WiFi.

According to an example, link capacity estimating component **13** and/or signal energy measuring component **20** can obtain or determine signal energy measurements of a serving cell, neighboring cells, total received energy, or the like, over one or more time periods. For example, link capacity estimating component **13** and/or signal energy measuring component **20** can obtain or measure one or more of: pilot energy of a pilot channel received from the serving node **14**, such as Ecp, which is a chip level energy of a Common Pilot Channel (CPICH); Ec, which is a chip level energy for a data channel, such as a High-Speed Physical Download Shared Channel (HS-PDSCH); Io, which is a total energy received from all cells, which can include cells of serving node **14** or neighboring node **16**; Nt, which is a total energy received from non-serving, and hence interfering, cells such as neighboring node **16**. In one example, the measurements (or combinations thereof) for one or more of the time periods can be logged by the signal energy measuring component **20**. The time periods can be fixed lengths of time, a subframe defined in the network, or the like

Additionally, link capacity estimating component **13** and/or SIR ratio determining component **23** can compute and store Ecp/Nt, based on the measured chip level energy of the CPICH and the measured total energy received from non-serving/interfering cells for one or more time periods.

Further, T2P ratio determining component **19** may determine and store an available T2P ratio for the cell for one or more time periods based on the measured Ecp, Nt, and To at one time period or over multiple time periods, based on the measured signal energies as described in more detail below. Alternatively, in an aspect, T2P ratio determining component **19** may determine and store an available T2P ratio based on receiving a given available T2P ratio from at least one network entity.

Also, MPO determining component **21** may determine and store an MPO. For example, MPO determining component **21** may access a memory location where a last received MPO is saved, and MPO determining component **21** may use the last received MPO as the MPO for use in the current available bandwidth calculations. Alternatively, MPO determining component **21** may store a given MPO to use as the MPO, such as when the last received MPO is not available or exceeds an age threshold corresponding to a time period in which the last received MPO may no longer represent a valid MPO for use in current calculations. In an aspect, the given MPO may be received from at least one network entity.

Accordingly, in one aspect, estimated available bandwidth may be a function of the estimated available link capacity plus the available T2P ratio, and factored according to the estimated available fraction of cell resources. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+T2Pavailable, and cell resources estimating component **15** and/or rate determining component **25** may access a rate look-up table, or execute an algorithm or function, to estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on the available number of codes and/or the TDM fraction to determine the estimated available bandwidth.

In another aspect, estimated available bandwidth may be a function of the estimated available link capacity plus MPO, and factored according to the estimated available fraction of cell resources. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+MPO, and cell resources estimating component **15** and/or rate determining component **25** may estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on the available number of codes and/or the TDM fraction to determine the estimated available bandwidth.

In a further aspect, estimated available bandwidth may be a function of the estimated available link capacity plus MPO and the available T2P ratio, and factored according to the estimated available fraction of cell resources, which also may be a function of a ratio of the available T2P ratio and the MPO. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+MPO, and cell resources estimating component **15** and/or rate determining component **25** may estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on the available number of codes, the ratio of T2Pavailable/MPO, and/or the TDM fraction to determine the estimated available bandwidth.

In yet another aspect, estimated available bandwidth may be a function of the estimated available link capacity plus the available T2P ratio, and factored according to the estimated available fraction of cell resources, which also may be a function of an average of the served number of codes. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+T2Pavailable, and cell resources estimating component **15** and/or rate determining component **25** may estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on an average of a served number of codes and/or the TDM fraction to determine the estimated available bandwidth.

In an additional aspect, estimated available bandwidth may be a function of the estimated available link capacity plus the MPO, and factored according to the estimated available fraction of cell resources, which also may be a function of an average of the served number of codes. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+MPO, and cell resources estimating component **15** and/or rate determining component **25** may estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on an average of a served number of codes and/or the TDM fraction to determine the estimated available bandwidth.

In another aspect, estimated available bandwidth may be a function of the estimated available link capacity plus the MPO, and factored according to the estimated available fraction of cell resources, which may be a function of an average of the served number of codes and a ratio of the available T2P ratio and the MPO. Specifically, in this aspect, link capacity estimating component **13** may calculate the estimated available link capacity of a cell as: Ec/Nt=Ecp/Nt+MPO, and cell resources estimating component **15** and/or rate determining component **25** may estimate a supported rate corresponding to the calculated Ec/Nt. TDM fraction determining component **29** determines a TDM fraction. Further, cell resources estimating component **15** and/or total bandwidth determining component **27** determines a total bandwidth corresponding to a total number of codes used by the cell for the supportable rate. Finally, cell resources estimating component **15** and/or scaling component **30** scales the total bandwidth based on an average of a served number of codes, the ratio of T2Pavailable/MPO, and/or the TDM fraction to determine the estimated available bandwidth.

Referring to FIG. **5**, in an aspect, a method **500** may be used for determining available downlink bandwidth while UE **11** is in an idle mode. Aspects of method **500** may be performed by link capacity estimating component **13**, cell resources estimating component **15**, bandwidth estimating component **17**, T2P determining component **19**, and/or MPO determining component **21**, as shown in various levels of detail in FIGS. **1**, **3**, and **4**.

At **510**, the method **500** includes estimating an available link capacity of a cell. In an aspect, the available link capacity of a cell may be estimated based on a signal-to-noise ratio (SNR) of a signal from the cell. For example, in an aspect, link capacity estimating component **13** may be configured to determine an estimated available link capacity based, at least in part, on measured signal energy and/or one or more determined SNR-related parameters, and optionally further based on T2Pavailable and/or MPO, as described herein.

Optionally, at **541**, the method **500** includes measuring signal energy received from a cell over multiple time periods. For example, in an aspect, link capacity estimating component **13** and/or signal energy measuring component **20** may be configured to perform or obtain these measurements, as described herein.

Optionally, at **543**, the method **500** includes determining a SNR for the cell. For example, in an aspect, link capacity estimating component **13** and/or signal-to-interference-plus-noise ratio determining component **23** may be configured to compute this ratio from the measured signal energy, as described herein.

Optionally, at **544**, the method **500** includes determining an available T2P ratio for the cell. For example, in an aspect, UE **11** may include T2P estimating component **19** configured to compute this ratio, at least in part, from the measured signal energy, as described herein.

Optionally, at **542**, the method **500** includes determining an MPO for the cell. For example, in an aspect, UE **11** may include MPO determining component **21** configured to determine the MPO based on prior used MPOs or a fixed MPO, as described herein.

At **520**, the method **500** includes estimating an available fraction of cell resources. In an aspect, the available fraction of cell resources may be estimated based on an available number of codes for the cell. For example, in an aspect, cell resources estimating component **15** may be configured to determine an estimated fraction of available cell resources based, at least in part, on an available number of codes (determined by code determining component **28**), and optionally further based on T2Pavailable, MPO, and/or a TDM fraction, as described herein.

At **530**, the method **500** includes estimating available bandwidth of the cell as a function of the available link capacity and the fraction of available cell resources. For example, in an aspect, bandwidth estimating component **17** may be configured to communicate with link capacity estimating component **13** and cell resources estimating component **15** to determine an available bandwidth for a cell, based at least in part on an SNR and an available number of codes, and optionally further based on T2Pavailable, MPO, and/or a TDM fraction as described herein.

Referring to FIG. **6**, in an aspect, a method **600** may be used for determining available downlink bandwidth while UE **11** is in an idle mode. Method **600** may include additional aspects of method **500**. Aspects of method **600** may be performed by link capacity estimating component **13**, cell resources estimating component **15**, bandwidth estimating component **17**, T2P determining component **19**, and/or MPO determining component **21**, as shown in various levels of detail in FIGS. **1**, **3**, and **4**.

At **510**, as described herein with respect to FIG. **5**, the method **600** includes estimating link capacity. The link capacity estimate may be based on SNR.

At **621**, the method **600** includes determining a supported rate based on the estimated link capacity. For example, in an aspect, rate determining component **25** may be configured to determine the supportable rate based on a calculated SNR-related parameter (determined by signal-to-interference-plus-noise ratio determining component **23**), as described herein.

At **623**, the method **600** includes determining a total bandwidth based on the supported rate. For example, in an aspect, total bandwidth determining component **27** may be configured to estimate a total bandwidth based on the supportable rate (determined by rate determining component **25**), as described herein.

At **622**, the method **600** includes determining an available number of codes. For example, in an aspect, code determining component **28** may be configured to estimate an available number of code parameter based on the supportable rate, as described herein.

At **624**, the method **600** includes determining a TDM fraction. For example, in an aspect, TDM fraction determining component **29** may be configured to determine a TDM fraction, as described herein.

At **625**, the method **600** includes scaling the total bandwidth based at least on an available number of codes and/or, optionally, the TDM fraction. For example, in an aspect, scaling component **30** may be configured to scale the total bandwidth based on the available number of codes and/or, optionally, a TDM fraction.

In an aspect, actions **621-625** may comprise estimating a fraction of cell resources, which is shown at **520** of method **500**. The fraction of cell resources may be estimated based on an available number of codes.

At **630**, the method **600** includes estimating an available bandwidth based on **510**, **621-625**.

As a result, at **530** of method **500**, the operation at **630** of estimating available bandwidth of the cell as a function of the available link capacity and the fraction of available cell resources, according to actions **510**, **621-625**, generates the estimated available bandwidth.

Referring to FIG. **7**, additional aspects of UE **11**, which may be used when UE **11** is in an idle mode and operating according to UMTS, are shown. UE **11** may include additional, optional, components within UE **11** and T2P determining component **19**, as shown having various levels of detail in FIGS. **1**, **3**, and **4**, for determining an available T2P ratio for a cell (e.g., performing action **544** of method **500**, described herein with respect to FIG. **5**). UE **11** optionally includes a signal energy measuring component **20**, which may be included within link capacity estimating component **13**, as shown in FIG. **4**, for measuring signal energy of a serving cell, neighboring cells, total received energy, or the like. UE **11** optionally may include a T2P determining component **19** (also shown in FIGS. **3** and **4**), which itself may include a T2P estimating component **22** for estimating a T2P ratio (e.g., an available T2P) at a cell based on one or more signal energy measurements and a T2P evaluating component **24** for evaluating a cell for communication based on the estimated T2P ratio. UE **11** can optionally include a handover component **26** for determining whether to handover communications from the cell based on the estimated T2P. The additional, optional, components shown within UE **11** and T2P determining component **19**, which are not shown as part of UE **11** in FIGS. **1**, **3**, and **4**, may optionally be used by UE **11** when operating in an idle mode and according to UMTS.

According to an example, signal energy measuring component **20** can obtain signal energy measurements in one or more time periods. For example, signal energy measuring component **20** can obtain measurements of total energy received from all cells (Io), which can include cells of serving node **14** or neighboring node **16**, or cells represented as nodes **14** and **16**. Moreover, for example, signal energy measuring component **20** can obtain measurements of energy received from non-serving cells (Nt), which can include neighboring node **16**, and/or measurements of pilot energy (Ec) received from the serving node **14**. In one example, the measurements (or combinations thereof) for one or more of the time periods can be logged by the signal energy measuring component **20**. The time periods can be fixed lengths of time, a subframe defined in the network, or the like

T2P estimating component **22** can estimate a T2P ratio for serving node **14** during a given time period based on at least some of the signal measurements. For example, signal energy measuring component **20** can compute the T2P ratio for serving node **14** based on the formula

$$\frac{Io - Nt}{Ec},$$

where Io, Nt, Ec are obtained by signal energy measuring component **20**. In another example, signal energy measuring component **20** can obtain or otherwise derive signal measurements related to serving node **14** as

$$\frac{Ec}{Io}$$

and

$$\frac{Ec}{Nt}.$$

In this example, T2P estimating component **22** can estimate T2P of the serving node **14** based on the formula

$$\left(\frac{Ec}{Io}\right)^{-1} - \left(\frac{Ec}{Nt}\right)^{-1}.$$

T2P estimating component **22** can further determine an available T2P based on the computed T2P ratio for a given time period and a maximum T2P ratio (e.g., by subtracting the computed T2P ratio for the given time period from the maximum T2P ratio).

For example, T2P estimating component **22** can determine the maximum T2P ratio of estimated T2P ratios for serving node **14** over a number of previous time periods. Thus, in this regard, T2P estimating component **22** can store the T2P measurements for a certain number of time periods, until an event occurs, and/or the like, and the T2P estimating component **22** can determine available T2P based in part on the maximum T2P ratio, as described herein. Moreover, in an example, T2P estimating component **22** can provide the determined maximum T2P ratio of the serving node **14** to a network component (not shown) for provisioning to one or more other UEs. In another example, T2P estimating component **22** can obtain the maximum T2P ratio for the serving node **14** from the network component, and can use the received maximum T2P ratio to determine available T2P at serving node **14**, as described. In addition, in one example, T2P estimating component **22** can apply a backoff_factor to the computed maximum T2P (e.g., for determining available T2P and/or for providing to the network component) to account for desired headroom at the serving node **14**. The backoff_factor or headroom can be received from a network component, serving node **14**, or the like In another example, the backoff_factor or headroom can be provided to a network component by T2P estimating component **22** (e.g., where determined or otherwise received from serving node **14**).

Furthermore, in an example, T2P evaluating component **24** can evaluate the serving node **14** for communication based on the available T2P as computed. In one example, T2P evaluating component **24** can compute a Ec/Nt available at serving node **14** by multiplying the available T2P by Ec/Nt. In another example, T2P evaluating component **24** can apply a resource assignment factor to the available T2P to determine an amount of the available T2P that the serving node **14** indicates can be provided to a single UE **11**. The resource assignment factor, for example, can be received from a network component, from serving node **14**, or the like In another example, the resource assignment factor can be provided to a network component by T2P evaluating component **24** (e.g., where determined or otherwise received from serving node **14**).

In any case, handover component **26**, in one example, can determine whether to handover from serving node **14** based on the available T2P (e.g., as modified by one or more factors, or otherwise). For example, this can include determining whether to recommend handover of UE **11** to serving node **14**, increasing a signal strength of one or more neighboring nodes reported in a measurement report for handover, such as neighboring node **16**, and/or the like.

In an alternative example, T2P estimating component **22** can determine the available T2P based on other calculations. For example, a UMTS cell, such as serving node **14**, transmits power over several orthogonal variable spreading factor (OVSF) codes. At spreading factor 16, for example, there are 16 such codes. Given the primary scrambling code (PSC) of serving node **14**, T2P estimating component **22** can compute the power received (−RxIor) by UE **11** over the 16 codes:

$$RxIor(t) = \sum_{i=0}^{15} RxPwr(OVSF \text{ code } i \text{ at time } t)$$

T2P estimating component **22** can then compute the maximum RxIor over time t:

$$\text{Max}RxIor = \max(RcIor(t)), \text{ over } t \text{ for the particular serving node}$$

Pilot Rx power at UE **11** can be the received signal code power (RSCP) measured by signal energy measuring component **20**. T2P estimating component **22** then determines the available T2P at serving node **14** as:

$$\frac{MaxRxIor - RxIor(t)}{RSCP}.$$

Referring to FIG. **8**, in one aspect, a method **800** may be for determining available downlink T2P at a cell. Aspects of method **800** may be performed by UE **11**, signal energy measuring component **20**, T2P determining component **19**, T2P estimating component **22**, T2P evaluating component **24**, and/or handover component **26**. In an aspect, UE **11** may perform aspects of method **800** while in an idle mode.

At **810**, the method **800** includes measuring signal energy received from a cell over multiple time periods. UE **11** and/or signal energy measuring component **20** may be configured to measure signal energy received from a cell over multiple time periods. For example, UE **11** and/or signal energy measuring component **20** may be configured to measure Ec of a serving cell or related node, Nt of neighboring cells or related nodes, Io of all received signals or other noise, or the like.

At **820**, the method **800** includes estimating a T2P ratio of the cell in each of the multiple time periods based in part on the signal energy. UE **11** and/or T2p determining component **19**, may be configured to estimate a T2P ratio of the cell in each of the multiple time periods based in part on the signal energy measured by UE **11** and/or signal energy measuring component **20**.

As described, UE **11** and/or T2P determining component **19** may be configured to compute the T2P ratio based on the signal energy measurements—e.g., as

$$\frac{Io - Nt}{Ec},$$

$$\left(\frac{Ec}{Io}\right)^{-1} - \left(\frac{Ec}{Nt}\right)^{-1},$$

or the like. UE **11** and/or T2P determining component **19** may be configured to do so in multiple time periods, as described, and stored for computing a maximum T2P, in one example.

At **830**, the method **800** includes determining an available T2P at the cell based on the T2P ratio estimated in one of the multiple time periods and a maximum T2P ratio corresponding to the multiple time periods. UE **11** and/or T2P determining component **19** may be configured to determine an available T2P at the cell based on the T2P ratio estimated in one of the multiple time periods, and determine a maximum T2P ratio corresponding to the multiple time periods. As described, the UE **11** and/or T2P determining component **19** may be configured to determine available T2P by subtracting the T2P ratio in a latest or current time period from the maximum T2P ratio. UE **11** and/or T2P determining component **19** may be configured to determine the maximum T2P ratio, as described herein, received from a network component, and/or the like. Moreover, UE **11** may be configured to apply a backoff_factor to the maximum T2P ratio, in one example. In a further example, UE **11** may be configured to apply a resource assignment factor to the available T2P. Additionally, UE **11** and/or handover component **26** may be configured to use the available T2P to evaluate the cell for communication (e.g., to determine whether to handover from the cell).

Referring to FIG. **9**, additional aspects of UE **11**, which may be used when UE **11** is in a connected mode and operating according to UMTS, are shown. UE **11** may include link capacity estimating component **13**, cell resources estimating component **15**, and bandwidth estimating component **17**, as described herein with respect to FIG. **1**. In an aspect, and optionally, UE **11** also may include a traffic-to-pilot (T2P) ratio determining component **19** for estimating a T2P ratio of a cell, and/or a measurement power offset (MPO) determining component **21** for estimating an MPO for a cell, where the available bandwidth of the cell may further be a function of the T2P ratio and/or the MPO. The additional, optional, components shown within UE **11**, link capacity estimating component **13**, and cell resources estimating component **15**, which are not shown as part of UE **11** in FIG. **1**, may optionally be used by UE **11** when operating in a connected mode and according to UMTS.

UE **11** and/or link capacity estimating component **13** may optionally include, in an aspect, channel quality index generating component **32** configured to generate a channel quality index at UE **11**. Channel quality index measures a channel quality and gives it a number, which can be mapped supportable rate for a given number of codes using a standardized table.

UE **11** and/or cell resources estimating component **15** may optionally include, in an aspect, rate determining component **25** configured to determine a supportable rate based on the channel quality index generated by channel quality index generating component **32**. UE **11** and/or cell resources estimating component **15** may include code determining component **28** configured to function as described herein. UE **11** and/or cell resources estimating component **15** may include partial bandwidth determining component **34** configured to determine a particular bandwidth corresponding to a total number of codes (determined by code determining component **28**) used by the cell for the supportable rate (determined by rate determining component **25**). UE **11** and/or cell resources estimating component **15** may include TDM fraction determining component configured to function as described herein. UE **11** and/or cell resources estimating component **15** may include scaling component **30** configured to scale the partial bandwidth based on at least one of an average served number of codes, a TDM fraction, and a ratio of T2Pavailable/MPO to determine the partial available bandwidth.

UE **11** also may optionally include, in an aspect, connected mode throughput determining component **33** configured to observe throughput for UE **11** per scheduled event over one or more past scheduling events. The throughput may be an average rate of successful message delivery from the UE **11** to the network. Thus, as such, UE **11** and/or bandwidth estimating component **17** may be configured to add the partial bandwidth determined by partial bandwidth determining component **34** to an observed connected mode throughput over one or more past scheduling events (determined by connected mode throughput determining component **33**) to determine the total available bandwidth.

Referring to FIG. **10**, in an aspect, a method **1000** may be used for determining available downlink bandwidth while UE **11** is in a connected mode. Aspects of method **1000** may be performed by link capacity estimating component **13**, cell resources estimating component **15**, bandwidth estimating component **17**, T2P determining component **19**, MPO determining component **21**, and/or connected mode throughput determining component **33**, as shown in FIG. **9**.

At **1010**, the method **1000** includes estimating an available link capacity of a cell for a user equipment. UE **11** and/or link capacity estimating component **13** may be configured to estimate an available link capacity of a cell for UE **11**. Optionally, at **1011**, the method **1000** may include generating a channel quality index at UE **11**. Channel quality index generating component **32** may be configured to generate a channel quality index. As such, and in an aspect, the method **1000** may include estimating an available link capacity of a cell for UE **11** based on the generated channel quality index. For example, link capacity estimating component **13** and/or channel quality index generating component **32**, may be configured to estimate an available link capacity of a cell for UE **11** based on the generated channel quality index.

In an aspect (not shown), UE **11** and/or link capacity estimating component **13**, in communication with cell resources estimating component **15**, may be configured to estimate available link capacity by determining (by rate determining component **25**) a supportable rate based on the channel quality index (determined by channel quality index generating component **32**), determining (by partial bandwidth determining component **34**) a partial bandwidth corresponding to a total number of codes used by the cell for the supportable rate, scaling (by scaling component **30**), the partial bandwidth based on at least one of an average served number of codes, a TDM fraction (determined by TDM fraction determining component **29**), and a ratio of T2Pavailable/MPO (determined by MPO determining component **21** and T2P determining component **19**) to determine the partial available bandwidth. UE **11** and/or bandwidth estimating component **17**, in communication with link capacity estimating component **13** and cell resources estimating component **15**, also may be configured to add the partial bandwidth to an observed connected mode throughput over one or more past scheduling events (determined by connected mode throughput determining component **33**) to determine the total available bandwidth.

At **1020**, the method **1000** includes estimating an available fraction of cell resources for the user equipment. UE **11** and/or cell resources estimating component **15** may be configured to estimate an available fraction of cell resources for UE **11**. Optionally, at **1021**, the method **1000** may include determining an available number of codes for the cell. For example, code determining component **28** may be configured to determine an available number of codes for the cell as described herein. As such, and in an aspect, the method **1000**, at **1020**, may include estimating an available fraction of cell resources for UE **11** based on an available number of codes for the cell. For example, UE **11**, cell resources estimating component **15**, and/or code determining component **28** may be configured to estimate an available fraction of cell resources for UE **11** based on an available number of codes for the cell (as determined by code determining component **28**).

Optionally, at **1025**, the method **1000** may include determining a connected mode throughput observed over one or more past scheduling events. For example, connected mode throughput determining component **33** may be configured to observe connected mode throughput for UE **11** per scheduling event over one or more past scheduling events.

At **1030**, the method **1000** includes estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources. UE **11** and/or bandwidth estimating component **17**, in communication with link capacity estimating component **13** and/or cell resources estimating component **15**, may be configured to estimate available bandwidth of the cell for UE **11**. In an aspect, the method **1000** may include estimating available bandwidth of the cell for the UE **11** as a function of the estimated available link capacity (determined by link capacity estimating component **13**), the estimated available fraction of cell resources (determined by cell resources estimating component **15**), and/or an observed connected mode throughput observed over one or more past scheduling events (determined by connected mode throughput determining component **33**).

In an additional aspect (not shown), UE **11** and/or T2P determining component **19**, may be configured to determine an available T2P ratio for the cell and UE **11** and/or MPO determining component **21** may be configured to determine an MPO, respectively, for the cell. In the aspect, cell resources estimating component **15** may be configured to estimate the available link capacity and/or the available fraction of cell resources based on the T2P ratio, the MPO, respectively, and/or the channel quality index.

FIG. **11** is a block diagram illustrating an example of a hardware implementation for an apparatus **1100** employing a processing system **1114**, which may be configured to implement the functional components and/or aspects illustrated in any, or all, of FIGS. **1-10** and FIGS. **16-19** (as described below with respect to UE **11** operating in an LTE system in an idle and/or connected mode). For example, apparatus **1100** may be specially programmed or otherwise configured to operate as UE **11** to determine an estimated available bandwidth of a cell and/or to determine an estimated available T2P ratio, serving node **14**, neighboring node **16**, or the like, as described herein.

In this example, the processing system **1114** may be implemented with a bus architecture, represented generally by the bus **1102**. The bus **1102** may include any number of interconnecting buses and bridges depending on the specific application of the processing system **1114** and the overall design constraints. The bus **1102** links together various circuits including one or more processors, represented generally by the processor **1104**, and computer-readable media, represented generally by the computer-readable medium **1106**. The bus **1102** may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further. A bus interface **1108** provides an interface between the bus **1102** and a transceiver **1110**. The transceiver **1110** provides a means for communicating with various other apparatus over a transmission medium. Depending upon the nature of the apparatus, a user interface **1112** (e.g., keypad, display, speaker, microphone, joystick) may also be provided.

The processor **1104** is responsible for managing the bus **1102** and general processing, including the execution of software stored on the computer-readable medium **1106**. The software, when executed by the processor **1104**, causes the processing system **1114** to perform the various functions described infra for any particular apparatus. The computer-readable medium **1106** may also be used for storing data that is manipulated by the processor **1104** when executing software. In an aspect, for example, processor **1104** and/or computer-readable medium **1106** may be specially programmed or otherwise configured to operate as UE **11**, serving node **14**, neighboring node **16**, or the like, as described herein.

The various concepts presented throughout this disclosure may be implemented across a broad variety of telecommunication systems, network architectures, and communication standards.

By way of example and without limitation, the aspects of the present disclosure illustrated in FIG. **12** are presented with reference to a UMTS system **1200** employing a W-CDMA air interface. A UMTS network includes three interacting domains: a Core Network (CN) **1204**, a UMTS Terrestrial Radio Access Network (UTRAN) **1202**, and User Equipment (UE) **1210**, which may be configured to operate as UE **11** to determine an estimated available bandwidth of a cell, or as UE **11** to determine an estimated available T2P ratio. In this example, the UTRAN **1202** provides various wireless services including telephony, video, data, messaging, broadcasts, and/or other services. The UTRAN **1202** may include a plurality of Radio Network Subsystems (RNSs) such as an RNS **1207**, each controlled by a respective Radio Network Controller (RNC) such as an RNC **1206**. Here, the UTRAN **1202** may include any number of RNCs **1206** and RNSs **1207** in addition to the RNCs **1206** and RNSs **1207** illustrated herein. The RNC **1206** is an apparatus responsible for, among other things, assigning, reconfiguring and releasing radio resources within the RNS **1207**. The RNC **1206** may be interconnected to other RNCs (not shown) in the UTRAN **1202** through various types of interfaces such as a direct physical connection, a virtual network, or the like, using any suitable transport network.

Communication between a UE **1210** and a Node B **1208** may be considered as including a physical (PHY) layer and a medium access control (MAC) layer. Further, communication between a UE **1210** and an RNC **1206** by way of a respective Node B **1208** may be considered as including a radio resource control (RRC) layer. In the instant specification, the PHY layer may be considered layer 1; the MAC layer may be considered layer 2; and the RRC layer may be considered layer 3. Information hereinbelow utilizes terminology introduced in the RRC Protocol Specification of some 3GPP technologies. Further, for example, UE **1210** may be specially programmed or otherwise configured to operate as UE **11**, and/or Node B **1208** as serving node **14**, neighboring node **16**, or the like, as described herein.

The geographic region covered by the RNS **1207** may be divided into a number of cells, with a radio transceiver apparatus serving each cell. A radio transceiver apparatus is commonly referred to as a Node B in UMTS applications, but may also be referred to by those skilled in the art as a base station (BS), a base transceiver station (BTS), a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), an access point (AP), or some other suitable terminology. For clarity, three Node Bs **1208** are shown in each RNS **1207**; however, the RNSs **1207** may include any number of wireless Node Bs. The Node Bs **1208** provide wireless access points to a CN **1204** for any number of mobile apparatuses. Examples of a mobile apparatus include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a notebook, a netbook, a smartbook, a personal digital assistant (PDA), a satellite radio, a global positioning system (GPS) device, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, or any other similar functioning device. The mobile apparatus is commonly referred to as a UE in UMTS applications, but may also be referred to by those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology. In a UMTS system, the UE **1210** may further include a universal subscriber identity module (USIM) **1211**, which contains a user's subscription information to a network. For illustrative purposes, one UE **1210** is shown in communication with a number of the Node Bs **1208**. The DL, also called the forward link, refers to the communication link from a Node B **1208** to a UE **1210**, and the UL, also called the reverse link, refers to the communication link from a UE **1210** to a Node B **1208**.

The CN **1204** interfaces with one or more access networks, such as the UTRAN **1202**. As shown, the CN **1204** is a GSM core network. However, as those skilled in the art will recognize, the various concepts presented throughout this disclosure may be implemented in a RAN, or other suitable access network, to provide UEs with access to types of CNs other than GSM networks.

The CN **1204** includes a circuit-switched (CS) domain and a packet-switched (PS) domain. Some of the circuit-switched elements are a Mobile services Switching Centre (MSC), a Visitor location register (VLR) and a Gateway MSC. Packet-switched elements include a Serving GPRS Support Node (SGSN) and a Gateway GPRS Support Node (GGSN). Some network elements, like EIR, HLR, VLR and AuC may be shared by both of the circuit-switched and packet-switched domains. In the illustrated example, the CN **1204** supports circuit-switched services with a MSC **1212** and a GMSC **1214**. In some applications, the GMSC **1214** may be referred to as a media gateway (MGW). One or more RNCs, such as the RNC **1206**, may be connected to the MSC **1212**. The MSC **1212** is an apparatus that controls call setup, call routing, and UE mobility functions. The MSC **1212** also includes a VLR that contains subscriber-related information for the duration that a UE is in the coverage area of the MSC **1212**. The GMSC **1214** provides a gateway through the MSC **1212** for the UE to access a circuit-switched network **1216**. The GMSC **1214** includes a home location register (HLR) **1215** containing subscriber data, such as the data reflecting the details of the services to which a particular user has subscribed. The HLR is also associated with an authentication center (AuC) that contains subscriber-specific authentication data. When a call is received for a particular UE, the GMSC **1214** queries the HLR **1215** to determine the UE's location and forwards the call to the particular MSC serving that location.

The CN **1204** also supports packet-data services with a serving GPRS support node (SGSN) **1218** and a gateway GPRS support node (GGSN) **1220**. GPRS, which stands for General Packet Radio Service, is designed to provide packet-data services at speeds higher than those available with standard circuit-switched data services. The GGSN **1220** provides a connection for the UTRAN **1202** to a packet-based network **1222**. The packet-based network **1222** may be the Internet, a private data network, or some other suitable packet-based network. The primary function of the GGSN **1220** is to provide the UEs **1210** with packet-based network connectivity. Data packets may be transferred between the GGSN **1220** and the UEs **1210** through the SGSN **1218**, which performs primarily the same functions in the packet-based domain as the MSC **1212** performs in the circuit-switched domain.

An air interface for UMTS may utilize a spread spectrum Direct-Sequence Code Division Multiple Access (DS-CDMA) system. The spread spectrum DS-CDMA spreads user data through multiplication by a sequence of pseudorandom bits called chips. The "wideband" W-CDMA air interface for UMTS is based on such direct sequence spread spectrum technology and additionally calls for a frequency division duplexing (FDD). FDD uses a different carrier frequency for the UL and DL between a Node B **1208** and a UE **1210**. Another air interface for UMTS that utilizes DS-CDMA, and uses time division duplexing (TDD), is the TD-SCDMA air interface. Those skilled in the art will recognize that although various examples described herein may refer to a W-CDMA air interface, the underlying principles may be equally applicable to a TD-SCDMA air interface.

An HSPA air interface includes a series of enhancements to the 3G/W-CDMA air interface, facilitating greater throughput and reduced latency. Among other modifications over prior releases, HSPA utilizes hybrid automatic repeat request (HARQ), shared channel transmission, and adaptive modulation and coding. The standards that define HSPA include HSDPA (high speed downlink packet access) and HSUPA (high speed uplink packet access, also referred to as enhanced uplink, or EUL).

HSDPA utilizes as its transport channel the high-speed downlink shared channel (HS-DSCH). The HS-DSCH is implemented by three physical channels: the high-speed physical downlink shared channel (HS-PDSCH), the high-speed shared control channel (HS-SCCH), and the high-speed dedicated physical control channel (HS-DPCCH).

Among these physical channels, the HS-DPCCH carries the HARQ ACK/NACK signaling on the uplink to indicate whether a corresponding packet transmission was decoded successfully. That is, with respect to the downlink, the UE **1210** provides feedback to the node B **1208** over the HS-DPCCH to indicate whether it correctly decoded a packet on the downlink.

HS-DPCCH further includes feedback signaling from the UE **1210** to assist the node B **1208** in taking the right decision in terms of modulation and coding scheme and precoding weight selection, this feedback signaling including the CQI and PCI.

"HSPA Evolved" or HSPA+ is an evolution of the HSPA standard that includes MIMO and 64-QAM, enabling increased throughput and higher performance. That is, in an aspect of the disclosure, the node B **1208** and/or the UE **1210** may have multiple antennas supporting MIMO technology. The use of MIMO technology enables the node B **1208** to exploit the spatial domain to support spatial multiplexing, beamforming, and transmit diversity.

Multiple Input Multiple Output (MIMO) is a term generally used to refer to multi-antenna technology, that is, multiple transmit antennas (multiple inputs to the channel) and multiple receive antennas (multiple outputs from the channel). MIMO systems generally enhance data transmission performance, enabling diversity gains to reduce multipath fading and increase transmission quality, and spatial multiplexing gains to increase data throughput.

Spatial multiplexing may be used to transmit different streams of data simultaneously on the same frequency. The data steams may be transmitted to a single UE **1210** to increase the data rate or to multiple UEs **1210** to increase the overall system capacity. This is achieved by spatially precoding each data stream and then transmitting each spatially precoded stream through a different transmit antenna on the downlink. The spatially precoded data streams arrive at the UE(s) **1210** with different spatial signatures, which enables each of the UE(s) **1210** to recover the one or more the data streams destined for that UE **1210**. On the uplink, each UE **1210** may transmit one or more spatially precoded data streams, which enables the node B **1208** to identify the source of each spatially precoded data stream.

Spatial multiplexing may be used when channel conditions are good. When channel conditions are less favorable, beamforming may be used to focus the transmission energy in one or more directions, or to improve transmission based on characteristics of the channel. This may be achieved by spatially precoding a data stream for transmission through multiple antennas. To achieve good coverage at the edges of the cell, a single stream beamforming transmission may be used in combination with transmit diversity.

Generally, for MIMO systems utilizing n transmit antennas, n transport blocks may be transmitted simultaneously over the same carrier utilizing the same channelization code. Note that the different transport blocks sent over the n transmit antennas may have the same or different modulation and coding schemes from one another.

On the other hand, Single Input Multiple Output (SIMO) generally refers to a system utilizing a single transmit antenna (a single input to the channel) and multiple receive antennas (multiple outputs from the channel). Thus, in a SIMO system, a single transport block is sent over the respective carrier.

Referring to FIG. **13**, an access network **1300** in a UTRAN architecture is illustrated, which may include one or more UEs to operate as UE **11** to determine an estimated available bandwidth of a cell, or to operate as UE **11** to determine an estimated available T2P ratio. The multiple access wireless communication system includes multiple cellular regions (cells), including cells **1302**, **1304**, and **1306**, each of which may include one or more sectors. The multiple sectors can be formed by groups of antennas with each antenna responsible for communication with UEs in a portion of the cell. For example, in cell **1302**, antenna groups **1312**, **1314**, and **1316** may each correspond to a different sector. In cell **1304**, antenna groups **1318**, **1320**, and **1322** each correspond to a different sector. In cell **1306**, antenna groups **1324**, **1326**, and **1328** each correspond to a different sector. The cells **1302**, **1304** and **1306** may include several wireless communication devices, e.g., User Equipment or UEs, which may be in communication with one or more sectors of each cell **1302**, **1304** or **1306**. For example, UEs **1330** and **1332** may be in communication with Node B **1342**, UEs **1334** and **1336** may be in communication with Node B **1344**, and UEs **1338** and **1340** can be in communication with Node B **1346**. Here, each Node B **1342**, **1344**, **1346** is configured to provide an access point to a CN **1204** (FIG. **12**) for all the UEs **1330**, **1332**, **1334**, **1336**, **1338**, **1340** in the respective cells **1302**, **1304**, and **1306**. For example, in an aspect, the UEs may be specially programmed or otherwise configured to operate as UE **11**, and/or Node Bs as serving node **14**, neighboring node **16**, or the like, as described herein.

As the UE **1334** moves from the illustrated location in cell **1304** into cell **1306**, a serving cell change (SCC) or handover may occur in which communication with the UE **1334** transitions from the cell **1304**, which may be referred to as the source cell, to cell **1306**, which may be referred to as the target cell. Management of the handover procedure may take place at the UE **1334**, at the Node Bs corresponding to the respective cells, at a radio network controller **1206** (FIG. **12**), or at another suitable node in the wireless network. For example, during a call with the source cell **1304**, or at any other time, the UE **1334** may monitor various parameters of the source cell **1304** as well as various parameters of neighboring cells such as cells **1306** and **1302**. Further, depending on the quality of these parameters, the UE **1334** may maintain communication with one or more of the neighboring cells. During this time, the UE **1334** may maintain an Active Set, that is, a list of cells that the UE **1334** is simultaneously connected to (e.g., the UTRA cells that are currently assigning a downlink dedicated physical channel DPCH or fractional downlink dedicated physical channel F-DPCH to the UE **1334** may constitute the Active Set).

The modulation and multiple access scheme employed by the access network **1300** may vary depending on the particular telecommunications standard being deployed. By way of example, the standard may include Evolution-Data Optimized (EV-DO) or Ultra Mobile Broadband (UMB). EV-DO and UMB are air interface standards promulgated by the 3rd Generation Partnership Project 2 (3GPP2) as part of the CDMA2000 family of standards and employs CDMA to provide broadband Internet access to mobile stations. The standard may alternately be Universal Terrestrial Radio Access (UTRA) employing Wideband-CDMA (W-CDMA) and other variants of CDMA, such as TD-SCDMA; Global System for Mobile Communications (GSM) employing TDMA; and Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, and Flash-OFDM employing OFDMA. UTRA, E-UTRA, UMTS, LTE, LTE Advanced, and GSM are described in documents from the 3GPP organization. CDMA2000 and UMB are described in documents from the 3GPP2 organization. The actual wireless communication standard and the multiple access technology employed will depend on the specific application and the overall design constraints imposed on the system.

The radio protocol architecture may take on various forms depending on the particular application. An example for an HSPA system will now be presented with reference to FIG. **14**. FIG. **14** is a conceptual diagram illustrating an example of the radio protocol architecture for the user and control planes.

Referring to FIG. **14**, the radio protocol architecture for a UE, such as a UE configured to operate as UE **11** to determine an estimated available bandwidth of a cell, or as UE **11** to determine an estimated available T2P ratio, and Node B is shown with three layers: Layer 1, Layer 2, and Layer 3. Layer 1 is the lowest lower and implements various physical layer signal processing functions. Layer 1 will be referred to herein as the physical layer **1406**. Layer 2 (L2 layer) **1408** is above the physical layer **1406** and is responsible for the link between the UE and Node B over the physical layer **1406**. For example, the UE utilizing the radio protocol architecture described here may be specially programmed or otherwise configured to operate as UE **11**, UE **11**, serving node **14**, neighboring node **16**, or the like, as described herein.

In the user plane, the L2 layer **1408** includes a media access control (MAC) sublayer **1410**, a radio link control (RLC) sublayer **1412**, and a packet data convergence protocol (PDCP) **1414** sublayer, which are terminated at the node B on the network side. Although not shown, the UE may have several upper layers above the L2 layer **1408** including a network layer (e.g., IP layer) that is terminated at a PDN gateway on the network side, and an application layer that is terminated at the other end of the connection (e.g., far end UE, server, or the like).

The PDCP sublayer **1414** provides multiplexing between different radio bearers and logical channels. The PDCP sublayer **1414** also provides header compression for upper layer data packets to reduce radio transmission overhead, security by ciphering the data packets, and handover support for UEs between node Bs. The RLC sublayer **1412** provides segmentation and reassembly of upper layer data packets, retransmission of lost data packets, and reordering of data packets to compensate for out-of-order reception due to hybrid automatic repeat request (HARQ). The MAC sublayer **1410** provides multiplexing between logical and transport channels. The MAC sublayer **1410** is also responsible for allocating the various radio resources (e.g., resource blocks) in one cell among the UEs. The MAC sublayer **1410** is also responsible for HARQ operations.

FIG. **15** is a block diagram of a system **1500** including a Node B **1510** in communication with a UE **1550**. For example, UE **1550** may be specially programmed or otherwise configured to operate as UE **11** to determine an estimated available bandwidth of a cell, or as UE **11** to determine an estimated available T2P ratio. Similarly, Node B **1510** may be configured to operate as serving node **14**, neighboring node **16**, or the like, as described herein. Further, for example, the Node B **1510** may be the same as or similar to Node B **1508**, and the UE **1550** may be the same as or similar to UE **11**. In the downlink communication, a transmit processor **1520** may receive data from a data source **1512** and control signals from a controller/processor **1540**. The transmit processor **1520** provides various signal processing functions for the data and control signals, as well as reference signals (e.g., pilot signals). For example, the transmit processor **1520** may provide cyclic redundancy check (CRC) codes for error detection, coding and interleaving to facilitate forward error correction (FEC), mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM), and the like), spreading with orthogonal variable spreading factors (OVSF), and multiplying with scrambling codes to produce a series of symbols. Channel estimates from a channel processor **1544** may be used by a controller/processor **1540** to determine the coding, modulation, spreading, and/or scrambling schemes for the transmit processor **1520**. These channel estimates may be derived from a reference signal transmitted by the UE **1550** or from feedback from the UE **1550**. The symbols generated by the transmit processor **1520** are provided to a transmit frame processor **1530** to create a frame structure. The transmit frame processor **1530** creates this frame structure by multiplexing the symbols with information from the controller/processor **1540**, resulting in a series of frames. The frames are then provided to a transmitter **1532**, which provides various signal conditioning functions including amplifying, filtering, and modulating the frames onto a carrier for downlink transmission over the wireless medium through antenna **1534**. The antenna **1534** may include one or more antennas, for example, including beam steering bidirectional adaptive antenna arrays or other similar beam technologies.

At the UE **1550**, a receiver **1554** receives the downlink transmission through an antenna **1552** and processes the transmission to recover the information modulated onto the carrier. The information recovered by the receiver **1554** is provided to a receive frame processor **1560**, which parses each frame, and provides information from the frames to a channel processor **1594** and the data, control, and reference signals to a receive processor **1570**. The receive processor **1570** then performs the inverse of the processing performed by the transmit processor **1520** in the Node B **1510**. More specifically, the receive processor **1570** descrambles and despreads the symbols, and then determines the most likely signal constellation points transmitted by the Node B **1510** based on the modulation scheme. These soft decisions may be based on channel estimates computed by the channel processor **1594**. The soft decisions are then decoded and deinterleaved to recover the data, control, and reference signals. The CRC codes are then checked to determine whether the frames were successfully decoded. The data carried by the successfully decoded frames will then be provided to a data sink **1572**, which represents applications running in the UE **1550** and/or various user interfaces (e.g., display). Control signals carried by successfully decoded frames will be provided to a controller/processor **1590**. When frames are unsuccessfully decoded by the receiver processor **1570**, the controller/processor **1590** may also use an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support retransmission requests for those frames.

In the uplink, data from a data source **1578** and control signals from the controller/processor **1590** are provided to a transmit processor **1580**. The data source **1578** may represent applications running in the UE **1550** and various user interfaces (e.g., keyboard). Similar to the functionality described in connection with the downlink transmission by the Node B **1510**, the transmit processor **1580** provides various signal processing functions including CRC codes, coding and interleaving to facilitate FEC, mapping to signal constellations, spreading with OVSFs, and scrambling to produce a series of symbols. Channel estimates, derived by the channel processor **1594** from a reference signal transmitted by the Node B **1510** or from feedback contained in the midamble transmitted by the Node B **1510**, may be used to select the appropriate coding, modulation, spreading, and/or scrambling schemes. The symbols produced by the transmit processor **1580** will be provided to a transmit frame processor **1582** to create a frame structure. The transmit frame processor **1582** creates this frame structure by multiplexing the symbols with information from the controller/processor **1590**, resulting in a series of frames. The frames are then provided to a transmitter **1556**, which provides various signal conditioning functions including amplification, filtering, and modulating the frames onto a carrier for uplink transmission over the wireless medium through the antenna **1552**.

The uplink transmission is processed at the Node B **1510** in a manner similar to that described in connection with the receiver function at the UE **1550**. A receiver **1535** receives the uplink transmission through the antenna **1534** and processes the transmission to recover the information modulated onto the carrier. The information recovered by the receiver **1535** is provided to a receive frame processor **1536**, which parses each frame, and provides information from the frames to the channel processor **1544** and the data, control, and reference signals to a receive processor **1538**. The receive processor **1538** performs the inverse of the processing performed by the transmit processor **1580** in the UE **1550**. The data and control signals carried by the successfully decoded frames may then be provided to a data sink **1539** and the controller/processor, respectively. If some of the frames were unsuccessfully decoded by the receive processor, the controller/processor **1540** may also use an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support retransmission requests for those frames.

The controller/processors **1540** and **1590** may be used to direct the operation at the Node B **1510** and the UE **1550**, respectively. For example, the controller/processors **1540** and **1590** may provide various functions including timing, peripheral interfaces, voltage regulation, power management, and other control functions. The computer readable media of memories **1542** and **1592** may store data and software for the Node B **1510** and the UE **1550**, respectively. A scheduler/processor **1546** at the Node B **1510** may be used to allocate resources to the UEs and schedule downlink and/or uplink transmissions for the UEs.

In an aspect, serving node **14** and neighboring node **16** may be operating according to a Long Term Evolution (LTE) communication standard. Such aspect may now be described with respect to FIGS. **16-25**. UE **11** may be in an idle mode or a connected mode at any given time.

Referring to FIG. **16**, additional aspects of UE **11**, which may be used when UE **11** is in an idle mode and operating according to LTE, are shown. The functional components of UE **11**, as shown in FIG. **16**, may be implemented by a hardware implementation for an apparatus **1100** employing a processing system **1114**, as described herein with respect to FIG. **11**. For example, apparatus **1100** may be specially programmed or otherwise configured to operate as UE **11** (having the components shown in, for example, FIG. **16**) as described herein.

As such, and in an aspect, an available bandwidth of a cell may be estimated for UE **11** based on an estimated available link capacity and an estimated available fraction of cell resources. The additional, optional, components shown within UE **11**, link capacity estimating component **13**, and cell resources estimating component **15**, which are not shown as part of UE **11** in FIG. **1**, may optionally be used by UE **11** when operating in an idle mode and according to LTE.

In an aspect, UE **11** and/or link capacity estimating component **13** may include a pilot energy determining component **40** for determining a pilot energy (Ep/Nt) for a cell (e.g., serving node **14**) in the dB domain. UE **11** and/or link capacity estimating component **13** may include a PDSCH-to-EPRE offset determining component **42** for determining a nominal Physical Downlink Shared Channel (PDSCH)-to-Energy Per Resource Element (EPRE) offset in the dB domain for a cell. UE **11** and/or link capacity estimating component **13** may include a PDSCH_SNR determining component **24** for determining a pilot tone signal-to-noise ratio (PDSCH_SNR) by combining the determined pilot energy (Ep/Nt) and the nominal PDSCH-to-EPRE offset. UE **11** and/or link capacity estimating component **13** may include PDSCH_SNR to link capacity converting component **46** for converting the PDSCH_SNR to a link capacity (link_capacity) value. The PDSCH_SNR may be converted to link capacity (e.g., a rate), in an aspect, using a CQI index-to-rate lookup table. In another aspect, the PDSCH_SNR may be converted to link capacity based on the Shannon capacity equation. In yet another aspect, a UE may be configured to map PDSCH_SNR with CQI indices while in the connected mode, which mapping could then be used by the UE in idle mode to convert the measured Reference Signal (RS) SNR to a CQI index in the idle mode. The UE may then use a CQI index-to-rate lookup table to determine a rate based on the CQI index.

In an aspect, UE **11** and/or cell resources estimating component **15** may include a resource block (RB) fraction (alpha_RB) determining component **21** and a Time-Domain Multiplexing (TDM) fraction (alpha_TDM) determining component **49**. The resource block fraction determining component **41** may include historical resource block allocation determining component **45** for determining a resource block fraction (alpha_RB) based on historical data. In an aspect, historical resource block allocation determining component **45** may determine a number of resource blocks that were allocated to the UE in the connected mode in the recent past (e.g., over a configurable time window of T seconds) when the traffic volume was above a configurable threshold (e.g., traffic volume was at least X bits during time window T).

The resource block fraction determining component **41** may include a default value **43**. In an aspect, and in the absence of enough history to determine the number of resource blocks, a default value may be used. For example, if the selected amount of time (e.g., the window of time T seconds) has not yet elapsed and/or if the traffic volume was not above a configurable threshold (e.g., was not at least X bits) during the window of time, the UE **11** may determine that there is not enough historical data to determine a number of resource blocks. As such, a default value may be used for the number of resource blocks. The resource block fraction determining component **41** may include T2P determining component **27** for determining a traffic-to-pilot (T2P) power transmitted from a cell during a configurable window of time when traffic volume was above a configurable threshold. Resource block fraction determining component **41** may be configured to determine a resource block fraction (alpha_RB) based on a number of resource blocks divided by a total number of resource blocks (assuming no traffic from other users). In an aspect, the number of resource blocks may be based on the determination by historical resource block allocation determining component **45**. In another aspect, the number of resource blocks may be based on default value **43**. In yet another aspect, the number of resource blocks may be based on the determination by T2P determining component **27**.

The TDM fraction (alpha_TDM) determining component **49** may determine information related to resource blocks provided to the UE **11** from the cell for every one out of a configurable number N of time transmission intervals (TTI). TDM fraction determining component **49** may base its determination on historical data by determining a number of resource blocks provided for every 1/N TTIs over a configurable time window when traffic volume was above a configurable threshold. TDM fraction determining component **49** may be configured to determine the TDM fraction (alpha_TDM) by determining an average of the historical data.

As such, and in an aspect, cell resources estimating component **15** may be configured to determine the estimated fraction of available cell resources (α) based on the output of the resource block fraction determining component **41** and the output of the TDM fraction determining component **49**. In other words, cell resources estimating component **15** may be configured to determine the estimated fraction of available cell resources (α) based on the product of alpha_RB*alpha_TDM.

In another aspect, a fraction of available cell resources may be provided to the UE, and then provided by the UE to the cell resources estimating component **15**, by at least one network entity. For example, the fraction of available cell resources may be provided to cell resources estimating component **15** by a serving eNodeB, a network node, a server, one or more other UEs (e.g., the value may be crowd-sourced), or any combination thereof. In such an aspect, the UE may not have to perform an estimation, but, rather, may use the provided value. In yet another aspect, the at least one network entity may provide alpha_RB and alpha_TDM to the UE, such that cell resources estimating component **15** may estimate a fraction of available cell resources (α) by alpha_RB*alpha_TDM as described herein.

Additionally, in a further optional aspect, UE **11** may additionally include a network communications component **31** for performing one or more network communications procedures based on the estimated available bandwidth for a cell, as determined by bandwidth estimating component **17**. For example, the network communication procedures performed by network communications component **31** may include, but are not limited to, a cell reselection procedure and a handover procedure.

Referring to FIG. **17**, a method **1700** may be used to estimate an available bandwidth of a cell (e.g., serving node **14**) for UE **11** while in the idle mode. For example, UE **11** and/or bandwidth estimating component **17**, in communication with link capacity estimating component **13** and cell resources estimating component **15**, and the additional, optional components, included therein, all of FIG. **16**, may be configured to estimate an available bandwidth of a cell for UE **11** while in the idle mode.

At **1710**, the method **1700** includes estimating an available link capacity of a cell for a user equipment based on channel quality measurements generated at the user equipment. For example, link capacity estimating component **13** may be configured to estimate an available link capacity of a cell for UE **11**. In an aspect, at **1712**, the method **1700** may include determining a pilot energy (Ep/Nt) in the dB domain. For example, pilot energy determining component **40** may be configured to determine a pilot energy (Ep/Nt) in the dB domain. In an aspect, at **1714**, the method **1700** may include determining a nominal Physical Downlink Shared Channel (PDSCH)-to-Energy Per Resource Element (EPRE) offset in the dB domain. For example, PDSCH-to-EPRE offset determining component **22** may be configured to determine a nominal Physical Downlink Shared Channel (PDSCH)-to-Energy Per Resource Element (EPRE) offset in the dB domain. In an aspect, at **1716**, the method **1700** may include determining a pilot tone signal-to-noise ratio (PDSCH_SNR) by summing the pilot energy (Ep/Nt) and nominal PDSCH-to-EPRE offset. For example, PDSCH_SNR determining component **24** may be configured to determine a pilot tone signal-to-noise ratio (PDSCH_SNR) by summing the pilot energy (Ep/Nt) and nominal PDSCH-to-EPRE offset.

In an aspect, at **1718**, the method **1700** may include converting the PDSCH_SNR to link capacity. For example, PDSCH_SNR to link capacity converting component **46** may be configured to convert the PDSCH_SNR to link capacity. The PDSCH_SNR may be converted to link capacity (e.g., a rate), in an aspect, using a CQI index-to-rate lookup table. In another aspect, the PDSCH_SNR may be converted to link capacity based on the Shannon capacity equation. In yet another aspect, a UE may be configured to map PDSCH_SNR with CQI indices while in the connected mode, which mapping could then be used by the UE in idle mode to convert the measured Reference Signal (RS) SNR to a CQI index in the idle mode. The UE may then use a CQI index-to-rate lookup table to determine a rate based on the CQI index.

At **1720**, the method **1700** includes estimating an available fraction of cell resources for the user equipment. For example, cell resources estimating component **15** may be configured to estimate an available fraction of cell resources for UE **11**. In an aspect, the available fraction of cell resources may be determined based on a resource block fraction (alpha_RB) and a TDM fraction (alpha_TDM).

In an aspect, at **1722**, the method **1700** includes determining a resource block fraction (alpha_RB). For example, resource block fraction determining component **41** may be configured to determine alpha_RB. In an aspect, historical resource block allocation determining component **45** may determine a number of resource blocks that were allocated to the UE in the connected mode in the recent past (e.g., over a configurable time window of T seconds) when the traffic volume was above a configurable threshold (e.g., traffic volume was at least X bits during time window T).

The resource block fraction determining component **41** may include a default value **43**. In an aspect, and in the absence of enough history to determine the number of resource blocks, a default value may be used. For example, if the selected amount of time (e.g., the window of time T seconds) has not yet elapsed and/or if the traffic volume was not above a configurable threshold (e.g., was not at least X bits) during the window of time, the UE **11** may determine that there is not enough historical data to determine a number of resource blocks. As such, a default value may be used for the number of resource blocks. The resource block fraction determining component **41** may include T2P determining component **27** for determining a traffic-to-pilot (T2P) power transmitted from a cell during a configurable window of time when traffic volume was above a configurable threshold. resource block fraction determining component **41** may be configured to determine a resource block fraction (alpha_RB) based on a number of resource blocks divided by a total number of resource blocks (assuming no traffic from other users). In an aspect, the number of resource blocks may be based on the determination by historical resource block allocation determining component **45**. In another aspect, the number of resource blocks may be based on default value **43**. In yet another aspect, the number of resource blocks may be based on the determination by T2P determining component **27**.

In an aspect, at **1724**, the method **1700** includes determining a Time-Domain Multiplexing (TDM) fraction (alpha_TDM). For example, TDM fraction determining component **49** may be configured to determine alpha_TDM. The TDM fraction (alpha_TDM) determining component **49** may determine information related to resource blocks provided to the UE **11** from the cell for every one out of a configurable number N of time transmission intervals (TTI). TDM fraction determining component **49** may base its determination on historical data by determining a number of resource blocks provided for every 1/N TTIs over a configurable time window when traffic volume was above a configurable threshold. TDM fraction determining component **49** may be configured to determine the TDM fraction (alpha_TDM) by determining an average of the historical data.

As such, UE **11** may estimate an available fraction of cell resources based on the product of alpha_RB and alpha_TDM.

In another aspect (not shown), a fraction of available cell resources may be provided to the UE, and then provided by the UE to the cell resources estimating component **15**, by at least one network entity. For example, the fraction of available cell resources may be provided to cell resources estimating component **15** by a serving eNodeB, a network node, a server, one or more other UEs (e.g., the value may be crowd-sourced), or any combination thereof. In such an aspect, the UE may not have to perform an estimation, but, rather, may use the provided value. In yet another aspect, the at least one network entity may provide alpha_RB and alpha_TDM to the UE, such that cell resources estimating component **15** may estimate a fraction of available cell resources (α) by alpha_RB*alpha_TDM as described herein.

At **1730**, the method **1700** includes estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources. For example, bandwidth estimating component **17** may be configured to estimate available bandwidth of the cell for UE **11** based on the estimated available link capacity and the estimated available fraction of cell resources (α).

In an aspect, at **1732**, the method **1700** may include applying a configurable backoff_factor to the product of the estimated link capacity and the estimated available fraction of cell resources. For example, bandwidth estimating component **17** may be configured to apply a configurable backoff_factor to the product of the estimated link capacity and the estimated available fraction of cell resources (α). To ensure the estimate of available downlink (DL) bandwidth is conservative (e.g., the estimate may be a lower bound), a configurable backoff_factor, or offset, may be applied to the function link_capacity (or rate)*α.

Referring to FIG. **18**, additional aspects of UE **11**, which may be used when UE **11** is in a connected mode and operating according to LTE, are shown. The functional components of UE **11**, as shown in FIG. **18**, may be implemented by a hardware implementation for an apparatus **1100** employing a processing system **1114**, as described herein with respect to FIG. **11**. For example, apparatus **1100** may be specially programmed or otherwise configured to operate as UE **11** (having the components shown in, for example, FIG. **18**) as described herein.

As such, and in an aspect, UE **11** may be configured to determine an available bandwidth at a cell for UE **11** based on an estimated available link capacity and an estimated available fraction of cell resources. More particularly, the estimated available bandwidth may be determined based on a rate (or link capacity) estimate in connected mode (R_calculated) and a measured throughput in connected mode (R_measured). The additional, optional, components shown within UE **11**, which are not shown as part of UE **11** in FIG. **1**, may optionally be used by UE **11** when operating in a connected mode and according to LTE.

UE **11** may include link capacity estimating component **13**, cell resources estimating component **15**, R_calculated determining component **50**, R_measured determining component **60**, and bandwidth estimating component **17** (not shown) in communication with one another.

UE **11** may include R_calculated determining component **50** for determining R_calculated based on the product of a rate, or link capacity (link_capacity), and an available fraction of cell resources (α). R_calculated determining component **50** may include Channel Quality Information (CQI) determining component **52** for measuring CQI at UE **11**. R_calculated may include T2P ratio determining component **54** for determining an available traffic-to-pilot ratio (T2P) at the cell. R_calculated may include TDM fraction determining component **56** for determining a TDM fraction.

An estimated fraction of available cell resources (α) may be determined by cell resources estimating component **15**, in an aspect, in a manner similar to that described herein for a UE in idle mode; however, CQI, as determined by CQI determining component **52**, may be used instead of a derived ratio of pilot energy-to noise-plus-interference (Ep/Nt) and the rate may be adjusted based on available traffic-to-pilot (T2P) ratio, as determined by T2P ratio determining component **54**, and the TDM fraction, as determined by TDM fraction determining component **56**.

UE **11** may include an R_measured determining component **60** for measuring throughput when UE **11** is in the connected mode. R_measured determining component **60** may include historical throughput determining component **62** for determining historical throughput data. Historical throughput determining component **62** may be configured to determine throughput measured at the UE in connected mode during a configurable time window.

In an aspect, and for example, when an offered load for the UE **11** is small, the connected mode estimate of available DL bandwidth may be based more heavily on R_calculated. When an offered load is large, the connected mode estimate of available DL bandwidth may be based more heavily on R_measured.

Additionally, in a further aspect, UE **11** may include a network communications component **31** for performing one or more network communications procedures based on the estimated available bandwidth for a cell, as determined by bandwidth estimating component **17**. For example, the network communication procedures performed by network communications component **31** may include, but are not limited to, a cell reselection procedure and a handover procedure.

Referring to FIG. **19**, a method **1900** may be used to estimate an available bandwidth of a cell (e.g., serving node **14**) for UE **11** while in the connected mode. For example, UE **11** and/or bandwidth estimating component **17**, in communication with link capacity estimating component **13**, cell resources estimating component **15**, R_calculated determining component **50**, and R_measured determining component **60**, all of FIG. **18**, may be configured to estimate an available bandwidth of a cell for UE **11** while in the connected mode.

At **1910**, the method **1900** includes estimating an available link capacity of a cell for a user equipment based on channel quality measurements generated at the user equipment. For example, link capacity estimating component **13** may be configured to estimate an available link capacity for UE **11** using any combination of the techniques described herein.

At **1920**, the method **1900** includes estimating an available fraction of cell resources for the user equipment. For example, cell resources estimating component **15** may be configured to estimate an available fraction of cell resources for UE **11** using, for example, and in an aspect, the techniques described herein with respect to actions **1922**, **1924**, and **1926**.

In an aspect, at **1922**, the method **1900** may include determining a channel quality information (CQI) at the user equipment. For example, cell resources estimating component **15** may be configured to communicate with CQI determining component **52**, within R_calculated determining component **50**, to determine CQI at UE **11**.

In an aspect, at **1924**, the method **1900** may include determining an available traffic-to-pilot (T2P) ratio at the cell. For example, cell resources estimating component **15** may be configured to communicate with T2P ratio determining component **44**, within R_calculated determining component **50**, to determining an available T2P ratio.

In an aspect, at **1926**, the method **1900** may include determining a TDM fraction. For example, cell resources estimating component **15** may be configured to communicate with TDM fraction determining component **46**, within R_calculated determining component **50**, to determine a TDM fraction. As such, the method **1900**, at **1920**, may include estimating the available fraction of cell resources based on the CQI, T2P ratio, and TDM fraction.

In another aspect (not shown), a fraction of available cell resources may be provided to the UE, and then provided by the UE to the cell resources estimating component **15**, by at least one network entity. For example, the fraction of available cell resources may be provided to cell resources estimating component **15** by a serving eNodeB, a network node, a server, one or more other UEs (e.g., the value may be crowd-sourced), or any combination thereof. In such an aspect, the UE may not have to perform an estimation, but, rather, may use the provided value. In yet another aspect, the at least one network entity may provide alpha_RB and alpha_TDM to the UE, such that cell resources estimating component **15** may estimate a fraction of available cell resources (α) by alpha_RB*alpha_TDM as described herein.

At **1930**, the method **1900** includes estimating available bandwidth of the cell for the user equipment as a function of the estimated available link capacity and the estimated available fraction of cell resources. For example, bandwidth estimating component **17** may be configured to estimate available bandwidth of the cell for UE **11** using, for example, and in an aspect, the techniques described herein with respect to actions **1932** and **1934**.

In an aspect, and at **1932**, the method **1900** may include determining a calculated value (R_calculated) based the product of the estimated link capacity of the cell for the user equipment and the estimated available fraction of cell resources. For example, R_calculated determining component **50** may be configured to determine R_calculated based on the product of the estimated link capacity of the cell, as determined by link capacity estimating component **13** and the estimated available fraction of cell resources, as determined by cell resources estimating component **15**.

In an aspect, and at **1934**, the method **1900** may include determining a measured value (R_measured) based on a measured throughput. For example, R_measured determining component **60** may be configured to measure throughput during a configurable window of time. In an aspect, and if there has not yet been enough historical data to support a determination of R_measured, R_measured determining component **60** may be configured to use a default value. As such, the available bandwidth may be estimated based on a function of R_calculated and R_measured.

In an aspect, and as described herein, FIG. **11** is a block diagram illustrating an example of a hardware implementation for an apparatus **1100** employing a processing system **1114**, which may be configured to implement the functional components and/or aspects illustrated in any, or all, of FIGS. **16-19**. FIG. **20** is a diagram illustrating an LTE network architecture **2000** in which UE **11** (discussed above) may operate. The LTE network architecture **2000** may be referred to as an Evolved Packet System (EPS) **2000**. The EPS **2000** may include one or more user equipment (UE) **2002**, an Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) **2004**, an Evolved Packet Core (EPC) **2010**, a Home Subscriber Server (HSS) **2020**, and an Operator's IP Services **2022**. UE **2002** may be, for example UE **11**.

The EPS can interconnect with other access networks, but for simplicity those entities/interfaces are not shown. As shown, the EPS provides packet-switched services, however, as those skilled in the art will readily appreciate, the various concepts presented throughout this disclosure may be extended to networks providing circuit-switched services.

The E-UTRAN includes the evolved Node B (eNB) **2006** and other eNBs **2008**. eNB **2006** and/or eNB **2008** may be, for example, serving node **14** and/or neighboring node **16**. The eNB **2006** provides user and control planes protocol terminations toward the UE **2002**. The eNB **2006** may be connected to the other eNBs **2008** via a backhaul (e.g., an X2 interface). The eNB **2006** may also be referred to as a base station, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The eNB **2006** provides an access point to the EPC **2010** for a UE **2002**. Examples of UEs **2002** include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, or any other similar functioning device. The UE **2002** may also be referred to by those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

The eNB **2006** is connected by an S1 interface to the EPC **2010**. The EPC **2010** includes a Mobility Management Entity (MME) **2012**, other MMEs **2014**, a Serving Gateway **2016**, and a Packet Data Network (PDN) Gateway **2018**. The MME **2012** is the control node that processes the signaling between the UE **2002** and the EPC **2010**. Generally, the MME **2012** provides bearer and connection management. All user IP packets are transferred through the Serving Gateway **2016**, which itself is connected to the PDN Gateway **2018**. The PDN Gateway **2018** provides UE IP address allocation as well as other functions. The PDN Gateway **2018** is connected to the Operator's IP Services **2022**. The Operator's IP Services **2022** may include the Internet, the Intranet, an IP Multimedia Subsystem (IMS), and a PS Streaming Service (PSS).

FIG. **22** is a diagram illustrating an example of an access network **2100** in an LTE network architecture in which UE **11** (discussed above) may operate. In this example, the access network **2100** is divided into a number of cellular regions (cells) **2102** in which a UE **2106**, which may be the same as or similar to UE **11** discussed above, may operate. One or more lower power class eNBs **2108** may have cellular regions **2110** that overlap with one or more of the cells **2102**. The lower power class eNB **2108** may be a femto cell (e.g., home eNB (HeNB)), pico cell, micro cell, or remote radio head (RRH). The macro eNBs **2104** are each assigned to a respective cell **2102** and are configured to provide an access point to the EPC **110** for all the UEs **2106** in the cells **2102**. There is no centralized controller in this example of an access network **2100**, but a centralized controller may be used in alternative configurations. The eNBs **2104** are responsible for all radio related functions including radio bearer control, admission control, mobility control, scheduling, security, and connectivity to the serving gateway **2116**.

The modulation and multiple access scheme employed by the access network **2100** may vary depending on the particular telecommunications standard being deployed. In LTE applications, OFDM is used on the DL and SC-FDMA is used on the UL to support both frequency division duplexing (FDD) and time division duplexing (TDD). As those skilled in the art will readily appreciate from the detailed description to follow, the various concepts presented herein are well suited for LTE applications. However, these concepts may be readily extended to other telecommunication standards employing other modulation and multiple access techniques. By way of example, these concepts may be extended to Evolution-Data Optimized (EV-DO) or Ultra Mobile Broadband (UMB). EV-DO and UMB are air interface standards promulgated by the 3rd Generation Partnership Project 2 (3GPP2) as part of the CDMA2000 family of standards and employs CDMA to provide broadband Internet access to mobile stations. These concepts may also be extended to Universal Terrestrial Radio Access (UTRA) employing Wideband-CDMA (W-CDMA) and other variants of CDMA, such as TD-SCDMA; Global System for Mobile Communications (GSM) employing TDMA; and Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, and Flash-OFDM employing OFDMA. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from the 3GPP organization. CDMA2000 and UMB are described in documents from the 3GPP2 organization. The actual wireless communication standard and the multiple access technology employed will depend on the specific application and the overall design constraints imposed on the system.

The eNBs **2104** may have multiple antennas supporting MIMO technology. The use of MIMO technology enables the eNBs **2104** to exploit the spatial domain to support spatial multiplexing, beamforming, and transmit diversity. Spatial multiplexing may be used to transmit different streams of data simultaneously on the same frequency. The data steams may be transmitted to a single UE **2106** to increase the data rate or to multiple UEs **2106** to increase the overall system capacity. This is achieved by spatially precoding each data stream (i.e., applying a scaling of an amplitude and a phase) and then transmitting each spatially precoded stream through multiple transmit antennas on the DL. The spatially precoded data streams arrive at the UE(s) **2106** with different spatial signatures, which enables each of the UE(s) **2106** to recover the one or more data streams destined for that UE **2106**. On the UL, each UE **2106** transmits a spatially precoded data stream, which enables the eNB **2104** to identify the source of each spatially precoded data stream.

Spatial multiplexing is generally used when channel conditions are good. When channel conditions are less favorable, beamforming may be used to focus the transmission energy in one or more directions. This may be achieved by spatially precoding the data for transmission through multiple antennas. To achieve good coverage at the edges of the cell, a single stream beamforming transmission may be used in combination with transmit diversity.

In the detailed description that follows, various aspects of an access network will be described with reference to a MIMO system supporting OFDM on the DL. OFDM is a spread-spectrum technique that modulates data over a number of subcarriers within an OFDM symbol. The subcarriers are spaced apart at precise frequencies. The spacing provides "orthogonality" that enables a receiver to recover the data from the subcarriers. In the time domain, a guard interval (e.g., cyclic prefix) may be added to each OFDM symbol to combat inter-OFDM-symbol interference. The UL may use SC-FDMA in the form of a DFT-spread OFDM signal to compensate for high peak-to-average power ratio (PAPR).

FIG. **22** is a diagram **2200** illustrating an example of a DL frame structure in LTE, which may be received by UE **11** (discussed above). A frame (10 ms) may be divided into 10 equally sized sub-frames. Each sub-frame may include two consecutive time slots. A resource grid may be used to represent two time slots, each time slot including a resource block. The resource grid is divided into multiple resource elements. In LTE, a resource block contains 12 consecutive subcarriers in the frequency domain and, for a normal cyclic prefix in each OFDM symbol, 7 consecutive OFDM symbols in the time domain, or 84 resource elements. For an extended cyclic prefix, a resource block contains 6 consecutive OFDM symbols in the time domain and has 72 resource elements. Some of the resource elements, as indicated as R **2202**, **2204**, include DL reference signals (DL-RS). The DL-RS include Cell-specific RS (CRS) (also sometimes called common RS) **2202** and UE-specific RS (UE-RS) **2204**. UE-RS **2204** are transmitted only on the resource blocks upon which the corresponding physical DL shared channel (PDSCH) is mapped. The number of bits carried by each resource element depends on the modulation scheme. Thus, the more resource blocks that a UE receives and the higher the modulation scheme, the higher the data rate for the UE.

FIG. **23** is a diagram **2300** illustrating an example of an UL frame structure in LTE, which may be transmitted by UE **11** (discussed above). The available resource blocks for the UL may be partitioned into a data section and a control section. The control section may be formed at the two edges of the system bandwidth and may have a configurable size. The resource blocks in the control section may be assigned to UEs for transmission of control information. The data section may include all resource blocks not included in the control section. The UL frame structure results in the data section including contiguous subcarriers, which may allow a single UE to be assigned all of the contiguous subcarriers in the data section.

A UE may be assigned resource blocks **2310***a*, **2310***b* in the control section to transmit control information to an eNB. The UE may also be assigned resource blocks **2320***a*, **2320***b* in the data section to transmit data to the eNB. The UE may transmit control information in a physical UL control channel (PUCCH) on the assigned resource blocks in the control section. The UE may transmit only data or both data and control information in a physical UL shared channel (PUSCH) on the assigned resource blocks in the data section. A UL transmission may span both slots of a subframe and may hop across frequency.

A set of resource blocks may be used to perform initial system access and achieve UL synchronization in a physical random access channel (PRACH) **2330**. The PRACH **2330** carries a random sequence and cannot carry any UL data/signaling. Each random access preamble occupies a bandwidth corresponding to six consecutive resource blocks. The starting frequency is specified by the network. That is, the transmission of the random access preamble is restricted to certain time and frequency resources. There is no frequency hopping for the PRACH. The PRACH attempt is carried in a single subframe (1 ms) or in a sequence of few contiguous subframes and a UE can make only a single PRACH attempt per frame (10 ms).

FIG. **24** is a diagram **2400** illustrating an example of a radio protocol architecture for the user and control planes in LTE, which may be implemented by UE **11** (discussed above). The radio protocol architecture for the UE and the eNB is shown with three layers: Layer 1, Layer 2, and Layer 3. Layer 1 (L1 layer) is the lowest layer and implements various physical layer signal processing functions. The L1 layer will be referred to herein as the physical layer **2406**. Layer 2 (L2 layer) **2408** is above the physical layer **2406** and is responsible for the link between the UE and eNB over the physical layer **2406**.

In the user plane, the L2 layer **2408** includes a media access control (MAC) sublayer **2410**, a radio link control (RLC) sublayer **2412**, and a packet data convergence protocol (PDCP) **2414** sublayer, which are terminated at the eNB on the network side. Although not shown, the UE may have several upper layers above the L2 layer **2408** including a network layer (e.g., IP layer) that is terminated at the PDN gateway on the network side, and an application layer that is terminated at the other end of the connection (e.g., far end UE, server, or the like).

The PDCP sublayer **2414** provides multiplexing between different radio bearers and logical channels. The PDCP sublayer **2414** also provides header compression for upper layer data packets to reduce radio transmission overhead, security by ciphering the data packets, and handover support for UEs between eNBs. The RLC sublayer **2412** provides segmentation and reassembly of upper layer data packets, retransmission of lost data packets, and reordering of data packets to compensate for out-of-order reception due to hybrid automatic repeat request (HARQ). The MAC sublayer **2410** provides multiplexing between logical and transport channels. The MAC sublayer **2410** is also responsible for allocating the various radio resources (e.g., resource blocks) in one cell among the UEs. The MAC sublayer **2410** is also responsible for HARQ operations.

In the control plane, the radio protocol architecture for the UE and eNB is substantially the same for the physical layer **2406** and the L2 layer **2408** with the exception that there is no header compression function for the control plane. The control plane also includes a radio resource control (RRC) sublayer **2416** in Layer 3 (L3 layer). The RRC sublayer **2416** is responsible for obtaining radio resources (i.e., radio bearers) and for configuring the lower layers using RRC signaling between the eNB and the UE.

FIG. **25** is a block diagram of an eNB **2510** in communication with a UE **2550** in an access network, where UE **2550** may be the same as or similar to UE **11** (discussed above). In the DL, upper layer packets from the core network are provided to a controller/processor **2575**. The controller/processor **2575** implements the functionality of the L2 layer. In the DL, the controller/processor **2575** provides header compression, ciphering, packet segmentation and reordering, multiplexing between logical and transport channels, and radio resource allocations to the UE **2550** based on various priority metrics. The controller/processor **2575** is also responsible for HARQ operations, retransmission of lost packets, and signaling to the UE **2550**.

The transmit (TX) processor **2516** implements various signal processing functions for the L1 layer (i.e., physical layer). The signal processing functions includes coding and interleaving to facilitate forward error correction (FEC) at the UE **2550** and mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols are then split into parallel streams. Each stream is then mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator **1274** may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE **2550**. Each spatial stream is then provided to a different antenna **2520** via a separate transmitter **1218**TX. Each transmitter **1218**TX modulates an RF carrier with a respective spatial stream for transmission.

At the UE **2550**, each receiver **2554**RX receives a signal through its respective antenna **2552**. Each receiver **2554**RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor **2556**. The RX processor **2556** implements various signal processing functions of the L1 layer. The RX processor **2556** performs spatial processing on the information to recover any spatial streams destined for the UE **2550**. If multiple spatial streams are destined for the UE **2550**, they may be combined by the RX processor **1256** into a single OFDM symbol stream. The RX processor **2556** then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, is recovered and demodulated by determining the most likely signal constellation points transmitted by the eNB **2510**. These soft decisions may be based on channel estimates computed by the channel estimator **2558**. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the eNB **2510** on the physical channel. The data and control signals are then provided to the controller/processor **2559**.

The controller/processor **2559** implements the L2 layer. The controller/processor can be associated with a memory **2560** that stores program codes and data. The memory **2560** may be referred to as a computer-readable medium. In the UL, the controller/processor **2559** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the core network. The upper layer packets are then provided to a data sink **2562**, which represents all the protocol layers above the L2 layer. Various control signals may also be provided to the data sink **2562** for L3 processing. The controller/processor **2559** is also responsible for error detection using an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support HARQ operations.

In the UL, a data source **2567** is used to provide upper layer packets to the controller/processor **2559**. The data source **2567** represents all protocol layers above the L2 layer. Similar to the functionality described in connection with the DL transmission by the eNB **2510**, the controller/processor **2559** implements the L2 layer for the user plane and the control plane by providing header compression, ciphering, packet segmentation and reordering, and multiplexing between logical and transport channels based on radio resource allocations by the eNB **2510**. The controller/processor **2559** is also responsible for HARQ operations, retransmission of lost packets, and signaling to the eNB **2510**.

Channel estimates derived by a channel estimator **2558** from a reference signal or feedback transmitted by the eNB **2510** may be used by the TX processor **2568** to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor **2568** are provided to different antenna **2552** via separate transmitters **2554**TX. Each transmitter **2554**TX modulates an RF carrier with a respective spatial stream for transmission.

The UL transmission is processed at the eNB **2510** in a manner similar to that described in connection with the receiver function at the UE **2550**. Each receiver **2518**RX receives a signal through its respective antenna **2520**. Each receiver **2518**RX recovers information modulated onto an RF carrier and provides the information to a RX processor **2570**. The RX processor **2570** may implement the L1 layer.

The controller/processor **2575** implements the L2 layer. The controller/processor **2575** can be associated with a memory **2576** that stores program codes and data. The memory **2576** may be referred to as a computer-readable medium. In the UL, the control/processor **2575** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the UE **2550**. Upper layer packets from the controller/processor **2575** may be provided to the core network. The controller/processor **2575** is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

As used in this application, the terms "component," "module," "system" and the like are intended to include a computer-related entity, such as but not limited to hardware, firmware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a computing device and the computing device can be a component. One or more components can reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers. In addition, these components can execute from various computer readable media having various data structures stored thereon. The components may communicate by way of local and/or remote processes such as in accordance with a signal having one or more data packets, such as data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems by way of the signal.

Furthermore, various aspects are described herein in connection with a terminal, which can be a wired terminal or a wireless terminal A terminal can also be called a system, device, subscriber unit, subscriber station, mobile station, mobile, mobile device, remote station, remote terminal, access terminal, user terminal, terminal, communication device, user agent, user device, or user equipment (UE). A wireless terminal may be a cellular telephone, a satellite phone, a cordless telephone, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a personal digital assistant (PDA), a handheld device having wireless connection capability, a computing device, or other processing devices connected to a wireless modem. Moreover, various aspects are described herein in connection with a base station. A base station may be utilized for communicating with wireless terminal(s) and may also be referred to as an access point, a Node B, or some other terminology.

Moreover, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from the context, the phrase "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, the phrase "X employs A or B" is satisfied by any of the following instances: X employs A; X employs B; or X employs both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from the context to be directed to a singular form.

The techniques described herein may be used for various wireless communication systems such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other systems. The terms "system" and "network" are often used interchangeably. A CDMA system may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, or the like. UTRA includes Wideband-CDMA (W-CDMA) and other variants of CDMA. Further, cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, or the like UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) is a release of UMTS that uses E-UTRA, which employs OFDMA on the downlink and SC-FDMA on the uplink. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). Additionally, cdma2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). Further, such wireless communication systems may additionally include peer-to-peer (e.g., mobile-to-mobile) ad hoc network systems often using unpaired unlicensed spectrums, 802.xx wireless LAN, BLUETOOTH and any other short- or long-range, wireless communication techniques.

Various aspects or features will be presented in terms of systems that may include a number of devices, components, modules, and the like. It is to be understood and appreciated that the various systems may include additional devices, components, modules, or the like and/or may not include all of the devices, components, modules or the like discussed in connection with the figures. A combination of these approaches may also be used.

The various illustrative logics, logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Additionally, at least one processor may comprise one or more modules operable to perform one or more of the steps and/or actions described herein.

Further, the steps and/or actions of a method or algorithm described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium may be coupled to the processor, such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. Further, in some aspects, the processor and the storage medium may reside in an ASIC. Additionally, the ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal. Additionally, in some aspects, the steps and/or actions of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a machine readable medium and/or computer readable medium, which may be incorporated into a computer program product.

In one or more aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored or transmitted as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection may be termed a computer-readable medium. For example, if software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs usually reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

While the foregoing disclosure discusses illustrative aspects and/or embodiments, it should be noted that various changes and modifications could be made herein without departing from the scope of the described aspects and/or embodiments as defined by the appended claims. Furthermore, although elements of the described aspects and/or embodiments may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Additionally, all or a portion of any aspect and/or embodiment may be utilized with all or a portion of any other aspect and/or embodiment, unless stated otherwise.

What is claimed is:

1. A method for determining available downlink bandwidth, comprising:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell, wherein a function of the supported rate comprises determining a total bandwidth corresponding to a total number of an available number of codes used by the cell for the supported rate;

estimating an available number of codes for the cell based at least in part on a number of codes per one or more past scheduling events, wherein a function of the available number of codes comprises scaling a total bandwidth based on at least one of an available number of codes;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available number of codes; and

performing, by the user equipment, one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

2. The method of claim **1**, wherein the cell is in a Universal Mobile Telecommunications System (UMTS) system.

3. The method of claim **2**, wherein the one or more network communications procedures includes handover to the cell when the user equipment is in a connected mode.

4. The method of claim **3**,

wherein the signal energy comprises a channel quality index generated at the user equipment;

and

wherein estimating the available bandwidth of the cell is further based at least in part on an observed connected mode throughput observed over the one or more past scheduling events.

5. The method of claim **4**, further comprising:

determining an available traffic-to-pilot (T2P) ratio for the cell; and wherein at least one of estimating the supported rate or estimating the available number of codes is further based on the available T2P ratio.

6. The method of claim **4**, further comprising:

determining a measurement power offset (MPO) for the cell; and

wherein at least one of estimating the supported rate or estimating the available number of codes is further based on the MPO.

7. The method of claim **6**, wherein determining the MPO further comprises identifying a last used MPO, and using the last used MPO as the MPO, or using a given MPO as the MPO.

8. The method of claim **4**, further comprising:

determining an available traffic-to-pilot (T2P) ratio for the cell;

determining a measurement power offset (MPO) for the cell; and

wherein estimating the supported rate is further based on at least one of the available T2P ratio, the MPO, and the channel quality index; and

wherein estimating the available number of codes is further based on at least one of the available T2P ratio or the MPO.

9. The method of claim **4**, further comprising determining the available number of codes for the cell according to one or more of:

averaging a served number of codes per past scheduling event based on one or more past scheduling events;

averaging a served number of codes per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold;

a fixed amount of codes when the one or more past scheduling events do not meet a freshness threshold; or

receiving code information from at least one network entity.

10. The method of claim **4**, further comprising determining an available time-division multiplexing (TDM) fraction for the user equipment, according to one or more of:

averaging TDM fractions per past scheduling event based on one or more past scheduling events;

averaging TDM fractions per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold;

a fixed TDM fraction when the one or more past scheduling events do not meet a freshness threshold; or

receiving TDM fraction information from at least one network entity

wherein estimating the available bandwidth of the cell is further based at least in part on the TDM fraction.

11. The method of claim **4**, wherein estimating the supported rate comprises:

determining the supported rate based on the channel quality index, and

wherein the function of the supported rate and the available number of codes comprises:

determining a partial bandwidth corresponding to a total number of codes used by the cell for the supported rate;

scaling the partial bandwidth based on at least one of an average served number of the available number of codes, a time-division multiplexing (TDM) fraction, and a ratio of T2Pavailable/MPO to determine the partial available bandwidth; and

combining the partial bandwidth to an observed connected mode throughput over one or more past scheduling events.

12. The method of claim **4**, wherein estimating an available number of codes comprises receiving the available number of codes from a network entity.

13. The method of claim **2**, wherein the one or more network communications procedures includes cell reselection to for the cell when the user equipment is in an idle mode.

14. The method of claim **13**,

wherein the measured signal energy comprises a signal-to-noise ratio (SNR) of a signal from the cell.

15. The method of claim **13**, further comprising:

determining an available traffic-to-pilot (T2P) ratio for the cell; and

wherein at least one of estimating the supported rate or estimating the available number of codes is further based on the available T2P ratio.

16. The method of claim **13**, further comprising:

determining a measurement power offset (MPO) for the cell; and

wherein at least one of estimating the supported rate or estimating the available number of codes is further based on the MPO.

17. The method of claim **16**, wherein determining the MPO further comprises identifying a last used MPO, and using the last used MPO as the MPO, or using a given MPO as the MPO.

18. The method of claim **13**, further comprising:

determining an available traffic-to-pilot (T2P) ratio for the cell;

determining a measurement power offset (MPO) for the cell; and

wherein estimating the supported rate is further based on at least one of the available T2P ratio or the MPO; and

wherein estimating the available number of codes is further based on at least one of the available T2P ratio or the MPO.

19. The method of claim **13**, further comprising determining the available number of codes for the cell according to one or more of:

averaging a served number of codes per past scheduling event based on the one or more past scheduling events;

averaging a served number of codes per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold;

a fixed amount of codes when the one or more past scheduling events do not meet a freshness threshold; or

receiving code information from a network entity.

20. The method of claim **13**, further comprising determining an available time-division multiplexing (TDM) fraction for a particular user equipment, according to one or more of:

averaging TDM fractions per past scheduling event based on the one or more past scheduling events;

averaging TDM fractions per past scheduling event for the one or more past scheduling events over a time period when an amount of data received satisfied at least a minimum amount of data threshold;

a fixed TDM fraction when the one or more past scheduling events do not meet a freshness threshold; or

receiving TDM fraction information from a network entity,

wherein estimating the available bandwidth of the cell is further based at least in part on the TDM fraction.

21. The method of claim 13, wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+T2Pavailable, wherein Ec is the signal energy represented as a chip level energy for a data channel (HS-PDSCH), Nt is a total energy received from one or more interfering cells, wherein Ecp is chip level energy of pilot channel (C-PICH), and wherein T2Pavailable is an available traffic-to-pilot (T2P) ratio for the cell; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of the available number of codes and a time-division multiplexing (TDM) fraction.

22. The method of claim 13, further comprising: wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+MPO, wherein Ec is the signal energy represented as a chip level energy for a data channel (HS-PDSCH), Nt is a total energy received from one or more interfering cells, wherein Ecp is chip level energy of pilot channel (C-PICH), and wherein MPO is a measurement power offset for the cell; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of the available number of codes and a time-division multiplexing (TDM) fraction.

23. The method of claim 13, further comprising: wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+MPO, wherein Ec is the signal energy represented as a chip level energy for a data channel (HS-PDSCH), Nt is a total energy received from one or more interfering cells, wherein Ecp is chip level energy of pilot channel (C-PICH), and wherein MPO is a measurement power offset for the cell; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of the available number of codes, a time-division multiplexing (TDM) fraction and a ratio of T2Pavailable/MPO, wherein T2Pavailable is an available traffic-to-pilot (T2P) ratio for the cell.

24. The method of claim 13, further comprising: wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+T2Pavailable, wherein Ec is the signal energy represented as a chip level energy for a data channel (HS-PDSCH), Nt is a total energy received from one or more interfering cells, wherein Ecp is chip level energy of pilot channel (C-PICH), and wherein T2Pavailable is an available traffic-to-pilot (T2P) ratio for the cell; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of an average served number of codes and a time-division multiplexing (TDM) fraction.

25. The method of claim 13, further comprising: wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+MPO, wherein Ec is the signal energy represented as a chip level energy for a data channel (HS-PDSCH), Nt is a total energy received from one or more interfering cells, wherein Ecp is chip level energy of pilot channel (C-PICH), and wherein MPO is a measurement power offset for the cell; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of an average served number of codes and a time-division multiplexing (TDM) fraction.

26. The method of claim 13, further comprising: wherein estimating the supported rate comprises:

determining Ec/Nt=Ecp/Nt+MPO; and

determining the supported rate based on the Ec/Nt; and wherein the function of the supported rate and the available number of codes comprises:

determining a total bandwidth corresponding to a total number of the available number of codes used by the cell for the supported rate; and

scaling the total bandwidth based on at least one of an average served number of codes, a time-division multiplexing (TDM) fraction, and a ratio of T2Pavailable/MPO.

27. A non-transitory computer-readable medium comprising computer-executable code for determining available downlink bandwidth, the computer-executable code for performing:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell, wherein a function of the supported rate comprises determining a total bandwidth corresponding to a total number of an available number of codes used by the cell for the supported rate;

estimating an available number of codes for the cell based at least in part on a number of codes per one or more past scheduling events, wherein a function of the available number of codes comprises scaling a total bandwidth based on at least one of an available number of codes;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available number of codes; and

performing one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

28. An apparatus for determining available downlink bandwidth, comprising:

means for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell, wherein a function of the supported rate comprises determining a total bandwidth corresponding to a total number of an available number of codes used by the cell for the supported rate;

means for estimating an available number of codes for the cell based at least in part on a number of codes per one or more past scheduling events, wherein a function of the available number of codes comprises scaling a total bandwidth based on at least one of an available number of codes;

means for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available number of codes; and

means for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

29. An apparatus for determining available downlink bandwidth, comprising:

at least one memory; and

at least one processor coupled with the at least one memory, wherein the at least one processor is configured to execute:

a link capacity estimating component for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell, wherein a function of the supported rate comprises determining a total bandwidth corresponding to a total number of an available number of codes used by the cell for the supported rate;

a cell resources estimating component for estimating an available number of codes for the cell based at least in part on a number of codes per one or more past scheduling events, wherein a function of the available number of codes comprises scaling a total bandwidth based on at least one of an available number of codes;

a bandwidth estimating component for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available number of codes; and

a network communications component for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

30. The apparatus of claim **29**, wherein the cell is in a Universal Mobile Telecommunications System (UMTS) system.

31. The apparatus of claim **30**, wherein the one or more network communications procedures comprises at least one of a cell reselection when the user equipment is in an idle mode or a handover when the user equipment is in a connected mode.

32. A method for determining available downlink bandwidth, comprising:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a resource block fraction (alpha_RB);

determining a Time-Domain Multiplexing (TDM) fraction (alpha_TDM) related to resource blocks provided for one out of a configurable number of time transmission intervals (TTI) when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the product of alpha_RB and alpha_TDM;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

performing, by the user equipment, one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

33. The method of claim **32**, wherein the cell is in a Long Term Evolution (LTE) system when the user equipment is in an idle mode.

34. The method of claim **33**, wherein estimating the supported rate comprises:

determining the signal energy as a pilot energy (Ep/Nt) in a decibel (dB) domain;

determining a nominal Physical Downlink Shared Channel (PDSCH)-to-Energy Per Resource Element (EPRE) offset in the dB domain;

determining a pilot tone signal-to-noise ratio (PDSCH_SNR) by summing the pilot energy (Ep/Nt) and nominal PDSCH-to-EPRE offset; and

converting the PDSCH_SNR to the supported rate.

35. The method of claim **34**, wherein converting the PDSCH_SNR to the supported rate comprises:

mapping PDSCH_SNR to Channel Quality Information (CQI) indices when the user equipment is in the connected mode; and

determining a CQI index from a measured SNR when the user equipment is in the idle mode based on the mapping.

36. The method of claim **33**, wherein estimating the available fraction of cell resources comprises receiving an available fraction of cell resources from at least one network entity.

37. The method of claim **36**, wherein the at least one network entity is at least one of the cell, another cell, a network node, a server, and other user equipment.

38. The method of claim **33**, wherein estimating the available fraction of cell resources comprises:

receiving the resource block fraction (alpha_RB) and the Time-Domain Multiplexing (TDM) fraction (alpha_TDM) from at least one network entity.

39. The method of claim **38**, wherein the at least one network entity is at least one of the cell, another cell, a network node, a server, and other user equipment.

40. The method of claim **32**, wherein determining the alpha_RB comprises determining a number of resource blocks that were allocated to the user equipment by the cell during a configurable window of time and when a traffic volume was above a configurable threshold.

41. The method of claim **32**, wherein determining the alpha_RB comprises: determining at least one condition including at least one of the configurable window of time is still open and the traffic volume was not above a configurable threshold during the configurable window of time; and determining the alpha_RB based on a default value in response to determining the at least one condition.

42. The method of claim **32**, wherein determining the alpha_RB comprises determining a total traffic-to-pilot (T2P) power transmitted from the cell during a configurable window of time and when traffic volume was above a configurable threshold; determining a total number of resource blocks available at the cell; and determining the alpha_RB based on a fraction of the total T2P and the total number of resource blocks.

43. The method of claim **32**, wherein determining the alpha_TDM comprises: determining a number of the resource blocks provided to the user equipment during the TTI during a configurable window of time and when traffic volume was above a configurable threshold; and determining the alpha_TDM by averaging the determined number of resource blocks.

44. The method of claim 33, further comprising determining a configurable backoff_factor, and

wherein estimating the available bandwidth of the cell is further based at least in part on applying the configurable backoff_factor to a product of the supported rate and the estimated available fraction of cell resources.

45. A method for determining available downlink bandwidth, comprising:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a Channel Quality Information (CQI) at the user equipment;

determining an available traffic-to-pilot (T2P) ratio at the cell;

determining a Time-Domain Multiplexing TDM fraction based on resource blocks assigned when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the CQI, the available T2P ratio, and the TDM fraction;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

performing, by the user equipment, one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

46. The method of claim 45, the cell is in a Long Term Evolution (LTE) system when the user equipment is in a connected mode.

47. The method of claim 46, wherein the function of the supported rate and the available fraction of cell resources comprises:

determining a calculated value (R_calculated) based a product of the estimated supported rate of the cell for the user equipment and the estimated available fraction of cell resources;

determining a measured throughput value (R_measured); and

determining a function of R_calculated and R_measured.

48. The method of claim 47, wherein determining the R_measured comprises measuring throughput during a configurable window of time.

49. The method of claim 47, wherein estimating an available fraction of cell resources comprises receiving at least one of an available fraction of cell resources, R_calculated, and R_measured from a network entity.

50. An apparatus for determining available downlink bandwidth, comprising:

at least one memory; and

at least one processor coupled with the at least one memory, wherein the at least one processor is configured to execute:

a link capacity estimating component for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

a cell resources estimating component for estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a resource block fraction (alpha_RB);

determining a Time-Domain Multiplexing (TDM) fraction (alpha_TDM) related to resource blocks provided for one out of a configurable number of time transmission intervals when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the product of alpha_RB and alpha_TDM;

a bandwidth estimating component for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

a network communications component for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

51. The apparatus of claim 50, wherein the bandwidth estimating component is further for estimating for the cell in a Long Term Evolution (LTE) system.

52. The apparatus of claim 51, wherein the bandwidth estimating component is further for estimating for the cell when the user equipment is in at least one of an idle mode or a connected mode.

53. A non-transitory computer-readable medium comprising computer-executable code for determining available downlink bandwidth, the computer-executable code for performing:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

estimating estimate an available fraction of cell resources for the user equipment based at least in part on:

determining a resource block fraction (alpha_RB);

determining a Time-Domain Multiplexing (TDM) fraction (alpha_TDM) related to resource blocks provided for one out of a configurable number of time transmission intervals when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the product of alpha_RB and alpha_TDM;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

performing one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

54. An apparatus for determining available downlink bandwidth, comprising:

means for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

means for estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a resource block fraction (alpha_RB);

determining a Time-Domain Multiplexing (TDM) fraction (alpha_TDM) related to resource blocks provided for one out of a configurable number of time transmission intervals when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the product of alpha_RB and alpha_TDM;

means for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

means for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

55. A non-transitory computer-readable medium comprising computer-executable code for determining available downlink bandwidth, the computer-executable code for performing:

estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a Channel Quality Information (CQI) at the user equipment;

determining an available traffic-to-pilot (T2P) ratio at the cell;

determining a Time-Domain Multiplexing TDM fraction based on resource blocks assigned when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the CQI, the available T2P ratio, and the TDM fraction;

estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

performing one or more network communications procedures with the cell based at least in part on the estimated available bandwidth.

56. An apparatus for determining available downlink bandwidth, comprising:

means for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

means for estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a Channel Quality Information (CQI) at the user equipment;

determining an available traffic-to-pilot (T2P) ratio at the cell;

determining a Time-Domain Multiplexing TDM fraction based on resource blocks assigned when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the CQI, the available T2P ratio, and the TDM fraction;

means for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

means for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

57. An apparatus for determining available downlink bandwidth, comprising:

at least one memory; and

at least one processor coupled with the at least one memory, wherein the at least one processor is configured to execute:

a link capacity estimating component for estimating a supported rate of a cell for a user equipment based at least in part on a measured signal energy of the cell;

a cell resources estimating component for estimating an available fraction of cell resources for the user equipment based at least in part on:

determining a Channel Quality Information (CQI) at the user equipment;

determining an available traffic-to-pilot (T2P) ratio at the cell;

determining a Time-Domain Multiplexing TDM fraction based on resource blocks assigned when the user equipment was in connected mode at the cell; and

estimating the available fraction of cell resources based on the CQI, the available T2P ratio, and the TDM fraction;

a bandwidth estimating component for estimating an available bandwidth of the cell for the user equipment as a function of the supported rate and the available fraction of cell resources; and

a network communications component for performing one or more network communications procedures based at least in part on the estimated available bandwidth.

58. The apparatus of claim **57**, wherein the cell is in a Long Term Evolution (LTE) system.

59. The apparatus of claim **58**, wherein the one or more network communications procedures comprises at least one of a cell reselection when the user equipment is in an idle mode or a handover when the user equipment is in a connected mode.

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